

Modeling Mercury Transport and Transformation along the Sudbury River, Massachusetts (USA) with Implications for Regulatory Action

VOLUME 1: Mercury Fate and Transport

Prepared for:

United States Environmental Protection Agency
Region I

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Abstract

Methyl mercury is an important environmental neurotoxin that requires ecological and human risk assessments for mercury-contaminated aquatic ecosystems. The Sudbury River, MA, USA, received tons of mercury loading from the Nyanza chemical waste site during its years of operation from 1917 to 1978, resulting in elevated levels of mercury in both sediments and fish, and an increased exposure risk to anglers who consume their catch. The Sudbury River is a hydrologically dynamic system, consisting of reservoirs, wetlands, and floodplains, with high flow and low flow periods during the year. A spatially-resolved, dynamic water quality mechanistic model was created using the Water quality Analysis Simulation Program (WASP7, v7.3) to investigate the mercury cycling within the Sudbury River, the possibility of long-term exposure risk, and evaluating the effectiveness of different remedial alternatives. The current state of mercury science and understanding does not permit mercury modeling with pre-determined parameterization. Therefore, the Sudbury River system was investigated using mechanistic modeling. This modeling suggests that the total mercury exposure risk within the Sudbury River system is attributable to a combination of: 1) mercury atmospherically deposited onto the Sudbury River watershed and its subsequent erosion and runoff to the Sudbury River, 2) the historical release of mercury from the Nyanza Site, and 3) the recycling, transformation and transport of background and Nyanza mercury. In certain reaches of the Sudbury River, the modeling suggests that the dominant fraction of mercury exposure risk is driven by the mercury loading coming from the watershed (originally from atmospheric deposition) with a secondary fraction due to the Nyanza site. In all reaches of the Sudbury River, both atmospheric and Nyanza-related mercury (*i.e.*, historical mercury deposits now in present in sediment) both contribute to the overall risk; however, the contribution [to the total risk] from these different sources varies and is reach dependent. For the earlier (upstream) reaches of the Sudbury River such as the Reservoirs, the modeling suggests that atmospheric deposition is a large source of mercury exposure risk. Further downstream, such as the Great Meadows National Wildlife Refuge (GMNWR), a larger fraction of the risk may be attributable to historic deposits of mercury associated with the former Nyanza facility. Exposure risks within the GMNWR are further complicated by the biogeochemical and hydrological properties of this 3,600-acre flood-plains and wetlands region.

1. Introduction

1.1. Site Description

The Sudbury River in eastern Massachusetts, USA, was contaminated with mercury (Hg) released from the Nyanza Chemical Waste Site (Nyanza site). The 14-acre Nyanza site was occupied by a series of companies, which manufactured various products, primarily textile dyes and dye intermediates, and operated from 1917 to 1978. During the period of operation, the companies disposed wastes, which were transported via overland flow into adjacent wetlands and reached the Sudbury River 300 meters (m) north of the Nyanza site. An estimated amount of 2,300 kg of mercury were used per year from 1940 to 1970 (JBF Scientific Corp., 1972, as cited in Supplemental Baseline Ecological Risk Assessment (SBERA); USEPA, 2007) and approximately 50,000 kg of mercury were released to the Sudbury River over this time (JBF Scientific Corp., 1973 as cited in SBERA, 2007). During this time, high levels of mercury were transported downstream and distributed throughout the Sudbury River system. The highest levels of sediment mercury concentration are located nearest to the site and generally decrease in concentration along the length of the river (Wiener and Shields, 2000).

The Sudbury River is a hydrologically complex and varying system that embodies several characteristics known to contribute to elevated concentrations of methyl mercury (MeHg). The Sudbury River flows approximately 60 km starting at the river's headwaters that drain Cedar Swamp Pond and extends to the confluence of the Sudbury River and the Assabet Rivers to form the Concord River. The Sudbury River flows through rolling, hilly terrain consisting of a suburban residential watershed of 165 square miles, passing through a series of impoundments, flowing reaches, wetlands and floodplains. The series of impoundments, wetlands, and floodplains are zones of increased methylation (see Table 1). A useful metric for interpreting methylation potential in an aquatic ecosystem is to use the %MeHg (the percent of total mercury present as methyl mercury. $\% \text{MeHg} = 100 * [\text{MeHg}] / [\text{MeHg} + \text{Hg(II)} + \text{Hg(0)}]$). Based on a series of empirical studies across different water body types across the U.S.A, a general trend of %MeHg was determined by calculating %MeHg for each water body type and taking the average of these values, as presented in Table 1.

Table 1. Percent Methyl Mercury:
Representative average %MeHg for different types
of water bodies

Water Body Type	Average %MeHg
River	4%
Lake	8%
Wetland	15%
Flooded Areas	30%

(Krabbenhoft et al., 1999; Kelly et al., 1995; Kelly et al., 1997).

This table reflects how the Sudbury River system can result in a large range of MeHg concentrations due to the range of water body types throughout the system.

1.2. Dynamic Hydrology

An additional facet of the Sudbury River is the highly dynamic nature of its hydrology. The Sudbury River follows a general pattern of high flow during the Spring and very low flow in the Summer. For example, the Saxonville gage reported a yearly high flow rate of $36 \text{ m}^3/\text{s}$ on April 18, 2007, and a yearly low of $0.1 \text{ m}^3/\text{s}$ from September 5 to 9, 2007. This wide range of flow rates affects the different parts of the system in different ways. To better understand the potential for varying MeHg concentrations throughout the river, the physical characteristics of the system along the length of the Sudbury River need to be understood. To understand the differences in the river's hydrology, the terms "flow velocity" and "volumetric flow rates" are used. Flow velocity refers to the actual speed with which the water is moving, in terms of length per time (e.g. m/s). Volumetric flow rate refers to the actual volume of water that is transported through a given section, this is measured in terms of volume per time (e.g., m^3/s). The velocity is related to the volumetric flow rate through the interfacial area that the water is moving through, *i.e.*, volumetric flow rate equals velocity multiplied by interfacial area.

The general construct of the Sudbury River system is a flowing stream before the Nyanza site, which flows into two Reservoirs (Reservoirs 1 and 2). The stream flows first into Reservoir 2, which consists of a series of lobes, and then into Reservoir 1. The impoundments at the end of each reservoir have resulted in created effective settling basins, *i.e.*, zones of increased settling of solids and associated mercury. Reservoir 1 receives inflow from both Reservoir 2 and from Reservoir 3 (the latter not directly impacted by the Nyanza Site). After Reservoir 1, the Sudbury River flows as a quickly flowing river until it reaches the Saxonville Impoundment, after which the river flows quickly again until it reaches the Great Meadows National Wildlife Refuge (GMNWR), where the Sudbury River follows a narrow channel surrounded by an expansive floodplain and associated wetlands ((3,600 acres delineated by US Fish & Wildlife Service, Refer to Figure 1).

During high flow periods, the depths in the Reservoirs increase only slightly, as the velocity of the water increases with the increasing flow rates. Increasing volumes of water overflow the impoundments and travel downstream. The river reaches between the impoundments and the GMNWR rise slightly during periods of high flow, but primarily the overall flow rates increase in response to high flow periods resulting in only small changes in depth. Once the river reaches the GMNWR, high flows cause the Sudbury River to overflow the banks of the channel and then fills the floodplain. With the increased surface area of the floodplain, the velocity of the river slows, while the overall volumetric flow rate remains constant, resulting in changes in depth in the GMNWR, but more importantly, dramatically large increases in the surface area of the water with the sediments and the atmosphere

During the low flow periods, the velocity of the water in the Reservoirs greatly slows down, so that the depth of the Reservoir approximates the height of the impoundment. Water within the river reaches between the impoundments and the GMNWR similarly slow down. As flow decreases, the water filling the floodplains of the GMNWR alongside the channel recede and

return to the much smaller cross-sectional area of the channel, where the water flows at a similar velocity, with a much volumetric lower flow rate.

Therefore, the flow fields of the Sudbury River vary depending on the given reach of the river. During low flow periods, the waters in the Reservoirs slow greatly and the reservoirs act more like lakes or large settling basins, with only the water near the surface overflowing into the downstream reaches. During the high flow periods, water rushes over the dams and the Reservoirs act more like rivers. The regions between the impoundments act like rivers all year long, with a more gently flowing period during low flow and more rushing river during the high flow. At all times, the GMNWR acts like a gently flowing river, simply increasing in the area, where the water is flowing to create higher flow rates with similar velocities. The water body type is clearly of importance as demonstrated by the different percentage of total mercury present as methyl mercury as outlined in Table 1.

1.3. Methylatation Potential in Different Parts of the Sudbury River

As previously discussed in Section 1.1, wetlands and areas prone to flooding are areas of increased MeHg production (refer to Table 1). Other (secondary) areas for increased MeHg production include lakes and areas of standing water or slow moving waters. Collectively, the areas of the Sudbury River with potential for increased MeHg production are: Reservoir 2, Reservoir 1, and the GMNWR. Therefore higher %MeHg is expected in these areas, with lower %MeHg in the river sections between these zones. The faster flowing reaches (Reach 5, 6, and 7) between the Reservoirs and the GMNWR likely act as conduits for transporting any incoming mercury (regardless if it is from atmospheric sources or historical mercury that may have been resuspended) downstream to the GMNWR which is an area for increased methylation (and correspondingly higher %MeHg). For the period of time when there is low flow in the Reservoirs and in the GMNWR, this could result in dispersion of dissolved Hg(II) and MeHg from the contaminated sediments, which would then be available to travel downstream as flow rates increase. The low flow period would also permit reduction of Hg(II) to Hg(0) and the subsequent evasion to the atmosphere, a loss process within the system. Depending on the residence time and the travel time along the river, there could be significant losses of Hg(II) or even demethylation of MeHg to Hg(II). Sedimentation and subsequent burial is an overall long-term loss process for mercury in the Sudbury River. However, the historic contamination in the sediments may periodically act as a secondary source to the water column in the near-term, while in the long-term the sediments will act as a net sink. The different physical, chemical, and biological processes governing cycling in the different sections of the Sudbury River may result in the sediments having different impacts on their overlying water column, and thus different associated mercury exposure risks.

1.4. Hypotheses

Given the understanding of the physical, chemical, biological and transport characteristics of the Sudbury River, the following are hypothesized:

1. Despite recent remediation in the vicinity of the Nyanza Site (OU3 –wetlands remediation), the years of mercury loading have impacted the downstream reaches (USEPA, 2008). Of particular interest are the elevated concentrations of total and methyl mercury in the sediments of Reservoir 2, Reservoir 1, and within the GMNWR.
2. During the low flow periods, the organic rich, depositional areas become sites of increased methylation, and MeHg and Hg(II) disperse from the sediments into the above surface water (Reservoir 2, Reservoir 1, and GMNWR). There are a few important competing factors. The first is that the low flow period results in an effective increased hydraulic residence time that permits transformation of Hg(II) to MeHg in the sediments and allows time for MeHg to diffuse into the water column. When water is flowing quickly, the impact of diffusion on overlying water column is diminished as incoming water flows quickly pushing the diffusing mercury downstream, so that the concentrations remain low. When the flow slows or stops, then the water has no incoming “clean” water and the mercury concentrations increase over time.
3. As MeHg may be periodically released from the sediment into the above flowing waters, it may potentially travel downstream, and accumulates as the system flows. When the system is flowing slowly, mercury is dispersing from the underlying sediment segment to the overlying water column segment, which is in addition to the incoming flow of upstream mercury. Therefore, each segment has the concentration of the upstream segment plus the dispersive flux. The diffusive flux is not associated with a incoming water flow, so it is an addition of concentrations, not an averaging (like one would see of two rivers flowing together). Therefore, it is feasible that concentrations of Hg and MeHg may increase along the river length.
4. There would be a decoupling of mercury concentrations between the underlying sediments and the above surface water, since the mercury concentrations in the water would reflect upstream loading as well as the additional source from the underlying sediments. Therefore a segment’s sediment mercury concentration may not accurately reflect the segment’s water mercury concentrations nor fish tissue concentrations. This corresponds to recent research demonstrating that there is not a significant relationship between MeHg concentration in sediments and the overlying water column MeHg in river and stream systems (Marvin-DiPasquale et al., 2009)
5. The regions where the sediments are cobbles, pebbles and sand may not accumulate mercury in the sediments, and they generally not zones of potential increased methylation. Therefore, it is reasonable that the river reaches between impoundments and the GMNWR will not be high in mercury, except during the flow periods when mercury is simply being carried downstream.
6. The surface water in the GMNWR does not have high velocities, which is different than the main river and the reservoirs. During high flow, the surface area of the GMNWR that the flow is passing through increases as the water fills the flood plain.

At almost all times, then, the flow in the GMNWR is slow, providing a high residence time for methylation of Hg(II) and diffusion up from the sediment layers as well as an increasing cross-sectional area for water column interaction with the sediments. At periods of high water, the GMNWR is a flooded wetland with a corresponding high potential for mercury methylation.

2. Model Selection

A dynamic, spatially resolved water quality model incorporating water and sediment layers was constructed using the WASP7 (v. 7.3) modeling framework with the mercury kinetics module. The Water Quality Analysis Simulation Program (WASP) has been used for a variety of regulatory (Lung and Nice, 2007; Zou et al., 2006) and research (Vuksanovic et al, 1996; Lindenschmidt, 2006) applications over the past several decades. An enhancement of the original WASP (Ambrose, 1987; Ambrose, 1988), WASP7 provides a dynamic, mass balance framework for modeling the fate and transport of a variety of contaminants in surface water systems. The WASP7 mercury module simulates three mercury species, Hg(0), Hg(II), and MeHg, as well as three solids types (silt, sand, and biotic solids) (Ambrose and Wool, 2001).

WASP7 was chosen to represent this system because of its flexible structure to handle spatial variability and temporal variability. WASP7 can be constructed in such a way as to handle the reservoirs, the Saxonville Impoundment, the fast flowing river reaches, and the floodplains. SERAFM (Knightes, 2008) is another USEPA mercury module, but it was designed specifically for lakes or ponds. Additionally, SERAFM is a steady-state model, which would not adequately address the highly dynamic hydrology of the system. The Mercury Cycling Models (MCM, R-MCM, and D-MCM) are also lake models, and are not currently constructed to handle river systems (EPRI, 2003; EPRI, 2006; Hudson et al., 1994; Tetra Tech, 1996; Tetra Tech, 1999).

3. Model Setup

The WASP7 model for the Sudbury River was set up by dividing the Sudbury River model region into 33 segments as shown in Figure 1. The map of the Sudbury River that was used to divide up the segments came from the NHDPlus (National Hydrology Dataset available at: <http://www.horizon-systems.com/nhdplus/>). Each segment represents a section of the Sudbury River, with a surface water component and an underlying sediment component. For most of the River (all regions downstream of Reservoir 1), there are two sediment layers, a surface benthic layer and a thicker deep subsurface benthic layer (Figure 2). For the Reservoirs, two additional sediment layers are added below the two top sediment layers, resulting in a total of four sediment layers under all surface water segments upstream of the Reservoir 1 impoundment (Figure 3). For the final segment of Reservoir 2 (segment 5), there is an additional surface water segment below the last 300m of Reservoir 2 (Figure 4). Under the first part of segment 5, there are 4 sediment layers, and under the last 300m of Reservoir 2, lies segment 100, to represent the deeper waters comprising a more defined settling basin. All surface water segments and sediment segments combined result in a total of 118 WASP segments as presented in Tables A-1 and A-2 (included in the appendix).

Table A-1 presents the segment numbers and segment names as defined in WASP7, with their volumes, lengths, widths and depths. The lengths and widths of each segment are constant for all sediment segments. The depth of the subsurface water segment, the deep section of the reservoir is held constant at 3m of depth. Depths of surface water segments vary with flow rates as described by the kinematic wave equations (see below). The associated reaches as defined by the Region I SBERA are presented alongside the surface water segment numbers. Table A-2 presents the segment type for each segment number. The segment types include surface and subsurface water column (for river/water segments), and surface benthic sediments and subsurface benthic sediments. Additionally, Table A-2 includes how the segments are stacked, by including the bottom segment, which points to what segment lies beneath a given segment number. Table A-2 also includes the segment slope, bottom roughness and minimum depth. Segment slope was determined from the NHDPlus dataset. Bottom roughness was determined using Manning's roughness coefficients for different surface materials (Schwab, 2005). The reservoir used $n=0.03$, for a natural stream, $n = 0.035$ for cobbley channel for the segments between the reservoir and the floodplain, and $n = 0.05$ for a floodplain with light brush. The segments upstream of the great meadows have increasing roughness as $n = 0.04, 0.04$, and 0.045 .

4. Model Processes

4.1. Simple Hydrology Routing: Kinematic Wave, Impoundments Implementation, and Hydraulic Geometry

Since WASP6, WASP7 routes water through the designated system using mass balance and momentum balance equations for water, with simplification down to the kinematic wave formulation (Chapra, 1997). This approach can only be used in linear routing systems, such as the river system of the Sudbury River, and allows for pulses of water being routed through the system so that increases in flow from a tributary needs time to travel through the river. With the dynamic nature of the flow in the Sudbury River system, the kinematic wave is necessary to adequately reflect the surface water hydrology. The kinematic wave incorporates the river slope and bottom roughness (Manning's coefficient) of a given segment to calculate the amount of water flowing out of one segment into the next. The kinematic wave equations calculate the velocity and depth of each segment based on the continuity equations.

A recent advance in WASP7 incorporates impoundments to permit flow over dams. A slope of 0 flags the segment as a dam and flow is modeled using the weir equations for a dam rather than kinematic wave for a continuous stream or river. The minimum depth for the segment is then used as the height of the dam, for which water will flow when this minimum height is exceeded, but water will not flow below this height. After depth calculation, a check versus the minimum depth (Table A-2), makes sure that that the minimum depth of the segment is maintained. Minimum depth is required for most segments (typically 0.01m) to ensure that volume doesn't approach zero (which can cause numerical instabilities in concentration calculations). For the network of river segments upstream of the impoundments, larger minimum depths are used to maintain reasonable upstream depths without imposing weir equations in the upstream reservoir reaches.

The hydraulic geometry of a WASP7 segment controls the width [L], depth [L] and velocity of flow [L/T] of each segment as a function of the volumetric flow rate [L^3/T]. The equations governing these relationships are as follows:

$$\text{width} = b_{\text{multi}} * Q^{b_{\text{exp}}} \quad \text{EQN 1}$$

$$\text{depth} = d_{\text{multi}} * Q^{d_{\text{exp}}} \quad \text{EQN 2}$$

$$\text{velocity} = v_{\text{multi}} * Q^{v_{\text{exp}}} \quad \text{EQN 3}$$

By changing the coefficients describing these relationships, different river reaches and segments can be modeled. In previous WASP releases, the width was maintained as a constant ($b_{\text{exp}} = 0$), so the more water in a given segment resulted in an increase in depth and velocity, but the width did not change. In effect, this resulted in a box or rectangular cross-section of the segment. The main channel of the Sudbury River was modeled with the shape of an eastern stream, such that the segment is parabolic. The width increases as the depth increases, increasing sharply at first and then increasing slower with increasing depths. This is executed by setting, $b_{\text{exp}} = 0.25$, $d_{\text{exp}} = 0.45$, and $v_{\text{exp}} = 0.3$. The floodplain was set up to capture a channel middle section with a slow slope above the channel. The depth function was defined so that the segment is 1m deep when the system is 20m wide and 2.25m deep when the segment is 200m wide.

4.2. Solids, Dynamic Settling and Resuspension

Solids in the system are modeled using 3 general solids types and a fourth WASP7-internal solid type. The three general solids include sands, silts/fines, biotic solids (particulate organic matter), and the internal solid type, cobbles. The solids are described generically in WASP7 so that they can be modeled specifically via site-specific parameterization. The three general solids types (sand, silts/fines, biotic solids) are modeled as state variables that have flow paths (resuspension, advective flow, settling, burial, and reaction (biotic solids grow and decay). The internal solid type, cobbles, cannot resuspend or settle, but is rather a solid that can only be buried. Cobbles are in the WASP modeling framework as a new feature of the upcoming version (WASP8) of WASP7, and have been added to WASP7 specifically because we identified their necessary inclusion in WASP during the Sudbury River project and modeling effort. Cobbles bury as other solid types settle and accumulate within a sediment segment, and cobbles may move into upper layers as erosion occurs, but cobbles will never resuspend to be transported downstream. Suspended solids (sands, silts, and biotic solids) all move along with the water phase in the surface water segments. They settle according to their modeled settling velocity, resuspend from the bottom sediment layer, and mix between surface water layers according to bulk mixing rates. The processes controlling solids are presented graphically in Figure 5.

Due to the dynamic nature of the flow field in the Sudbury River, a new feature has been implemented into the WASP7 for this study, and will be available to the public in the upcoming release of WASP8 that calculates settling and resuspension as a function of flow velocity, shear stress, and particle size. As velocity increases the shear stress along the underlying sediment increases, thereby increasing the suspension velocity. Conversely, as velocity increases, settling

velocity decreases. The formulation in WASP7 describing settling and resuspension as a function of the cohesiveness of the sediment bed, the shear stress, the critical shear stress of the sediments has been described in Lick (2008). A base minimum resuspension rate is given for each solids type. With the highly dynamic nature of the Sudbury River flow, it became evident that an immovable solid was necessary to more accurately represent the system. Additionally, several river segments were observed in the field to be dominated by pebbles and cobbles, and not silts, sands, or clays.

4.3. Partitioning

Mercury sorbs to solid particles and complexes with dissolved organic carbon. These processes are modeled by assuming instantaneous partitioning and complexation. Elemental mercury is assumed to not partition or complex. Divalent and methyl mercury each sorb to sand, silts, and biotic solids and complex with dissolved organic carbon (DOC). Mercury is modeled as not sorbing to cobbles. All of these processes compete with each other and are modeled simultaneously and instantaneously in each segment for Hg(II) and MeHg for each time step (see Figure 6).

4.4. Mercury Transformation Processes

Mercury concentrations are simulated in the water column and in sediments for three mercury species (elemental mercury, Hg(0), divalent inorganic mercury, Hg(II), and methylmercury (methylated divalent mercury) MeHg). Transformation processes among species are generally represented by first-order and pseudo-first order rate constants. The modeled mercury processes are presented in Figure 7 and include:

- methylation of Hg(II) to MeHg in water and sediments,
- demethylation of MeHg to Hg(II) in water and sediments,
- photo-reduction of Hg(II) to Hg(0) in water,
- photo-oxidation of Hg(0) to Hg(II) in water,
- volatilization of Hg(0) from the water into the air, and
- photo-degradation of MeHg to Hg(0) in water.

4.5. Mercury Transport Processes

Mercury is transported through the physical processes of advection as water flows from one segment to the next, dispersion between horizontal layers, volatilization of Hg(0) from the water column to the air, via settling of mercury sorbed to solid particles, resuspension of mercury sorbed to solid particles, and burial and erosion of particles from sediment layers. Ultimate loss processes of total mercury from the Sudbury River system include volatilization losses and burial from the lowest sediment layer. Additionally, mass advected out of the last Sudbury River segment is a net loss of total mercury from the system.

5. Model Application

The Sudbury River model was constructed using WASP7 proceeding step-by-step through each of the underlying parts of the overall model. Modeling a complex river network system, like the Sudbury River, requires many decisions on how best to set up and apply a mathematical model, each with different sources of uncertainty and error within the overall model construction. To minimize the complications caused by model development, calibration and verification, this step-by-step approach was used so that each step could be defined in a clear and transparent way. The first step of constructing the mercury fate and transport model was to delineate the segmentation of the Sudbury River, as detailed in Section 3 - Model Setup. Next, the flow field and hydrodynamics of the system was constructed, as detailed below, in Section 5.1 - Flow Field / Hydrodynamics. The modeled flow field, including volumetric flow rates, velocities, and modeled depths of the system were compared to observed values to constrain the hydrodynamics. Next, the solids balance was developed as detailed in Section 5.2 - Solids Balance. This part is compared to the observed solids concentrations in the water column, the observed burial rates for different Sudbury River segments, and the solid type distributions in available sediment segments.

5.1. Flow Field/Hydrodynamics

The hydrology of the Sudbury River is highly dynamic with periods of high flow and periods of low flow. To adequately account for this, USGS discharge gage data for points along the Sudbury River were used to determine incoming flows from feeding tributaries in the model system. Gage data were collected by USGS from October 1, 2006 through September 30, 2008. Gage locations included the Ashland Gage, Saxonville Gage, and the Concord Gage. Locations within the Reservoir Reaches and the Wetland (GMNWR) Reach were estimated using watershed drainage area for each location. Measurements of volumetric flow rates were taken at Route 135, Reservoir 2 Outflow, Reservoir 1 Outflow, Route 20 and Route 117. These values for flow (provided as cubic feet per second) were implemented in the model to establish the upstream flow boundary (into segment 1), additional flow into Reservoir 2 (Segment 2), additional flow into Reservoir 1 from Reservoir 2 (Segment 5), incoming from the Sudbury Reservoir, Reservoir 3 (Segment 6), flow into Saxonville Dam (Reach 13), and at Route 20 (Reach 24). Additionally, flow into the wetland reach was divided amongst each of the reaches to account for the tributaries feeding into the wetlands reach. The total flow for the wetlands reach was divided by 11 to distribute the flow based on watershed drainage area, 1/11 was directed into the first seven segments, Segments 25 – 31, totaling 7/11 of the overall flow and 4/11 was added to segment 32 (these fractions of flow are related to the drainage area of each segment) to account for all 11 parts of the flow. The flow field was looped every two years to provide a 30 year flow-field for the entire system. The data used for determining the flow field are provided in the appendix. The actual flow inputs for a two year flow period are similarly provided in the appendix.

The flow rates at the specified gages were compared to the observed flow rates and were found to match closely. The depths of the reservoirs and the great meadows flood plains and the velocities were also evaluated. The water velocities and depths of the great meadows were found to fluctuate more than observed, so the bottom roughness parameters were adjusted within the ranges acceptable for floodplains until the velocities and depths approached observed values, depths were roughly 1m at low flow and roughly 2m at high flow with little variation in observed velocity.

5.2. Solids Balance

Once the hydrology of the system was set up, the solids in the system were incorporated into the model next. The total organic carbon (TOC) and percent solids were used as the starting point for the solids throughout the system. TOC and percent solids values were available for all of the reaches, but not specifically for each segment within each reach (see Table 2-8, SBERA (USEPA, 2008)). The percent solids was used to directly calculate the starting total abiotic solids concentration and the TOC concentration was used to calculate the particulate organic matter (POM) starting concentration by dividing TOC by 0.3. From the sediment grain size distribution of Reservoir 2, a starting fraction of abiotic solids as silts and sands was established. Rough estimates of percent silts and sands were estimated as starting concentrations based on observed descriptions of sediment types, because no further information was available.

From the 2007 to 2008 sampling events, total suspended solids (TSS), TOC, and DOC were used to determine observed abiotic and biotic solids concentrations. Biotic solids concentration was determined as TOC minus DOC. Abiotic solids were determined as TSS minus biotic solids. All abiotic solids were modeled to be silts, assuming that any sands would settle out rather quickly in the system. Using the observed concentrations, the boundary concentrations for incoming flows were determined. Boundary concentrations of silts were modeled to be 120% of the observed to account for settling within the system. Because biotic solids are created within stream, the boundary concentrations of biotic solids were modeled exactly as observed. Using the modeled initial conditions, the model was run for 100 years to let the model approach steady state solids concentrations within the sediment layers. Looking at the resulting curves for the sediment layers, these results suggested that a steady-state concentration in the surface layer segments was reached.

5.3. Mercury Cycling

Once the hydrodynamics and solids balance WASP7 model was established for the Sudbury River system, WASP7 was then used to incorporate the incoming mercury concentrations with the inflows and the current conditions of mercury concentrations observed in the sediment layers. One of the challenges in modeling mercury at contaminated sediment sites is the difficulty with capturing the incoming concentrations from atmospheric deposition leading to watershed runoff and tributary inflow. In riverine systems, atmospheric mercury deposited directly to the surface water itself (via dry deposition or wet deposition through rainfall) has been demonstrated to be negligible. For the Sudbury River system all incoming mercury concentrations separate from the historical (Nyanza associated) accumulation in the sediments is accounted for via inflowing boundary concentration conditions. These inflowing boundary concentrations capture all mercury coming in to the system via tributaries and at the upstream boundaries (particularly the start of the modeling system at the head of Reservoir 2 (Reach 2 into Reach 3), inflow coming into Reservoir 1 from Reservoir 3 (Foss Reservoir), since Reservoir 3 and upstream of it are not being directly modeled). These inflowing boundaries account for all mercury coming off the watershed from atmospheric sources and is typically described as background mercury levels. A series of different models were developed to evaluate different approaches for handling mercury in the Sudbury River network. Unfortunately, mercury science and understanding is not currently at a point where mercury fate, transformation, and transport can be predicted *a priori*, some level of

calibration is typically required. However, as with many numerical mathematical representations, there can be different representations that provide similar responses. Therefore, the best way to approach these different mechanistic representations is to evaluate a range of different modeling approaches. Then, by comparing the different mechanistic approaches and parameterizations, we can compare the model results with the observations to investigate how the model is responding in comparison to the observed concentrations. Then some mechanistic inference can be made with respect to how the system is responding, certain representations can be thrown out, constraining the possible bounds of future predictions of the system.

6. Parameterization

6.1. Partitioning of mercury amongst the different phases

Partitioning is an important environmental process for mercury because of the highly hydrophobic nature of Hg(II) and MeHg, and thus the high partition and complexation coefficients. The two species, Hg(II) and MeHg, partition between the different phases modeled in the system. These are represented by the fraction, f , of each, represented as constituent i , for each given phase, where the phases are: freely dissolved in the aqueous phase, aq ; complexed with dissolved organic carbon, DOC ; organic matter, org ; and sorbed to sand, $sand$, and fines (silts and clays), $silts$. The partitioning of Partition coefficients are used to represent the ratio of constituent i . The partition coefficients were assumed to be constant for the entire system, whether in the sediments or in the water column. For each observations site, the mean TSS, DOC, TOC, unfiltered and filtered MeHg and HgT concentrations were used to predict the fraction dissolved (freely dissolve plus DOC complexed).

$$f_{aq,i} = \frac{1}{1 + 10^{-6}(K_{silts,i} \times S_{silts} + K_{sands,i} \times S_{sands} + K_{org,i} \times S_{org} + K_{DOC,i} \times DOC)}$$

$$f_{silts,i} = \frac{10^{-6} \times K_{silts,i} \times S_{silts}}{1 + 10^{-6}(K_{silts,i} \times S_{silts} + K_{sands,i} \times S_{sands} + K_{org,i} \times S_{org} + K_{DOC,i} \times DOC)} = 10^{-6} \times K_{silts,i} \times S_{silts} \times f_{aq,i}$$

$$f_{sands,i} = \frac{10^{-6} \times K_{sands,i} \times S_{sands}}{1 + 10^{-6}(K_{silts,i} \times S_{silts} + K_{sands,i} \times S_{sands} + K_{org,i} \times S_{org} + K_{DOC,i} \times DOC)} = 10^{-6} \times K_{sands,i} \times S_{sands} \times f_{aq,i}$$

$$f_{org,i} = \frac{10^{-6} \times K_{org,i} \times S_{org}}{1 + 10^{-6}(K_{silts,i} \times S_{silts} + K_{sands,i} \times S_{sands} + K_{org,i} \times S_{org} + K_{DOC,i} \times DOC)} = 10^{-6} \times K_{org,i} \times S_{org} \times f_{aq,i}$$

$$f_{DOC,i} = \frac{10^{-6} \times K_{DOC,i} \times S_{DOC}}{1 + 10^{-6}(K_{silts,i} \times S_{silts} + K_{sands,i} \times S_{sands} + K_{org,i} \times S_{org} + K_{DOC,i} \times DOC)} = 10^{-6} \times K_{DOC,i} \times S_{DOC} \times f_{aq,i}$$

Using the fraction dissolved observed, the fraction dissolved was predicted giving the partition coefficients. For each sample location, the goal seek feature was used to find an abiotic solids partition coefficient so that modeled equaled predicted. The mean of the K_{silts} from all sites was used in the WASP model. For lack of more precise site-specific data, default values for K_{DOC} , K_{sand} , K_{org} were used (see

Table 2).

Table 2. Default Partitioning Coefficients

Partition Coefficients for Hg(0), Hg(II) and MeHg to silts, sands, and particulate organic matter and complexation with dissolved organic carbon (DOC).

Parameter	sorbent	Hg(0)	Hg(II)		MeHg	
			Model	Literature	Model	Literature
K_{silts}	Silts and Clays	0	1.3×10^6	$(1.6 \times 10^4 - 7.9 \times 10^6)$	2.0×10^5	2.5×10^5
K_{sand}	Sands	0	1×10^3		1×10^2	
K_{org}	Particulate Organic Matter	0	4×10^5		5×10^5	
K_{DOC}	Dissolved Organic Carbon (DOC)	0	2×10^5	$(2.0 \times 10^5 - 4.0 \times 10^5)$	2.5×10^5	1.0×10^5
					1×10^5	$(6.3 \times 10^2 - 3.2 \times 10^5)$

Allison and Allison (2000), listed as mean (minimum – maximum).

6.2. Settling, Resuspension and Burial

A hydrodynamic and sediment transport study of the Sudbury River reported a critical shear stress (where erosion began) at 0.2 Pa, yet earlier in the study a critical shear stress was determined to be 0.4 Pa. At 0.4 Pa erosion was 0.002 kg/m²/min and at 0.6 Pa the rate increased to 0.01 kg/m²/min (US ACoE, 2001). Using this report as the starting point for the simulation, a range of values based around these numbers were used to evaluate solids transport in the system and compared to the observed % solids in the different segments along the Sudbury River. The value of 0.4 N/m² may be a little low for this system, believing that some level of compaction at the site may result in a larger critical shear stress than the study presented, so a value of 0.6 Pa was used (personal communication Earl Hayter, 2009). Some parameter exploration showed that using critical shear stresses of 0.2 or 0.4 Pa resulted in large erosion events that did not reflect the observed solids distributions present in the SBERA. Because there is no further information on the site, and WASP is currently limited to having one constant for each solid type in the system, the same parameters are used throughout the Sudbury River, assuming that the silts, sands, and POM all act similarly throughout the system. The model uses 0.2 as the critical cohesive sediment fraction, and a shear stress multiplier for cohesive resuspension of 2.5.

Grain size distribution data for Reservoir 2 divided particulates into sands (>0.075mm) and silts and clays (<0.075mm). Sands were divided into gravel (>4.75mm), coarse sand (2.0 - 4.75 mm), medium to fine sand (0.106-2.0 mm), and very fine sand (0.075 – 0.106 mm). Based on observed distributions of sand in Reservoir 2, mean sand size was set to 0.400 mm. No information was available on the silt and clay distributions, only the total percent <0.075 mm. Particle diameter for silt was set to 0.025mm and particle diameter for particulate organic matter (POM) was set to 0.025 mm. Default values for lower and upper critical shear stresses for sand and POM were used

since there was no other available information; these values are 0.1 Pa and 0.2 Pa for sand and 0.0 Pa and 0.05 Pa for POM, respectively.

WASP sediments are stacked in a column to allow for accumulation and erosion of solid particles in the sediment layers. The model is constructed so that the top layer is allowed to gain or lose thickness and every 10 days the sediment thickness is compared to the starting thickness. If the thickness has increased (settling) then solids are pushed into the segment below (burial), if the thickness had decreased (erosion), then the segment below is pulled up into the upper segment. This can result in the deepest layer getting smaller over time if there is continual erosion. If there is continual burial, then the lowest layer will stay the same size and the buried solids are removed from the system completely. Mercury mass moves with the sediments, so deeper sediments can receive or lose mercury depending on the overall flux. The burial rate is calculated as the velocity of the segment (cm/yr) that is pushed downward.

The observed burial rates for Reservoir 2, Reservoir 1 and the floodplains are approximately 0.04 cm/yr, 0.07 cm/yr and 0.02 cm/yr (Frazier et al., 2000). The model predicted rates of 0.03 cm/yr in Reservoir 2, 0.04 cm/yr in Reservoir 1, and -0.03 cm/yr in the GMNWR. The measured settling rate in the GMNWR was for the floodplains, while the modeled erosion is accounting for the channel and the floodplain, which is modeled as a single, homogeneous segment.

6.3. Mercury Transformation Rate Constants

The mercury transformation processes were discussed briefly in Section 4.4 Mercury transformation processes and represented in Figure 7. The modeling structure of WASP permits different rate constants for different transformation processes for each segment. Beer-Lambert law is applied to photo-lytic processes to account for light attenuation with depth. Methylation and demethylation are modeled as biotic processes, and thus have temperature correction factors, θ , where $k_{meth} = k_{meth, base} \bullet \theta^{(T-20)}$ with T in degrees Celsius. Rate constants are presented in Table 3.

Table 3. Mercury transformation processes, with overall reaction, with base rate constants for all media.

Transformation Process (rate)	Reaction	Water Column	Water: Deep Reservoir	Reservoir Sediments	Main River Sediments	GMNWR Sediments
Methylation (d^{-1}) ^{a,b}	$Hg(II) \rightarrow MeHg$	0 ^a	0.0 ^a	0.02 ^b	0.02 ^b	0.02 ^b
Demethylation (d^{-1}) ^{b,c}	$MeHg \rightarrow Hg(II)$	0.04 ^c	0.04 ^c	0.5 ^b	0.7 ^b	0.25 ^b
Methylation/ Demethylation (%MeHg)		0	25%	4%	3%	8%
Dark Oxidation ^d	$Hg(0) \rightarrow Hg(II)$	1.6 ^d	1.6 ^d	0	0	0
Surface Photo-Oxidation (d^{-1}) ^e	$Hg(0) \rightarrow Hg(II)$	6 ^e	0	0	0	0
Surface Photo-Reduction (d^{-1}) ^f	$Hg(II) \rightarrow Hg(0)$	14 ^f	0	0	0	0
Surface Photo-Demethylation (d^{-1}) ^g	$MeHg \rightarrow Hg(0)$	0.2 ^g	0	0	0	0

^a Water-column methylation rate constants from Eckley and Hintelmann, Gilmour and Henry, and USEPA.

^b Sediment methylation demethylation rate constants calibrated to the observed fraction MeHg (MeHg = MeHg/HgT x 100%) using relationships reported by Matilainen and Verta. Methylation rates in sediments were held constant at 0.02 d⁻¹ and demethylation rate was varied to approximate %MeHg as represented by surface water body type as listed in Table 1.

^c Water-column demethylation rate constants from Matilainen and Verta (1995).

^d Dark oxidation rate constant from LaLonde et al (2001). No dark oxidation occurs in the sediments.

^e Water-column photo-oxidation rate constants from Amyot et al (2000) and LaLonde et al (2001). No photo-oxidation occurs in the sediment.

^f Water-column reduction rate constants from Mason et al (1995) and O'Driscoll et al. (2003). No photo-reduction occurs in the sediment.

^g Photo-demethylation rate constant in water from Sellers et al (1996). No photo-demethylation occurs in the sediment.

6.4. Constants

There are additional constants required for the model parameterization, describing different processes that are constant throughout the entire system and are presented in Table 4, and include parameters for light extinction through the water column, volatilization rates for Hg(0), and dispersion between segment layers.

Table 4. Parameter Constants for the Sudbury River model.

Constant	Value
Light Extinction Coefficient	1.05 per m ^a
Wavelength of maximum absorption for photo-lytic processes	420 nm ^b
Temperature correction factor for biotic processes	2 ^c
Hg(0) Volatilization Option	4: O'Connor Method ^d
Hg(0) Atmospheric Concentration	1.6x10 ⁻⁹ g/m ³ ^d
Hg(0) Henry's Law Constant	0.01 atm-m ³ /mole ^d
Hg(0) Volatilization Temperature Correction, θ	1.04 ^d
Macro-Dispersive Exchange for Deep Reservoir	0.00162 cm ² /s ^e
Pore Water Dispersion between sediment layers	6x10 ⁻⁶ cm ² /s ^f
Pore Water Dispersion between sediment layer and surface water	5x10 ⁻⁵ cm ² /s ^{e,g}

^a Wetzel, 2001.

^b Wavelength of violet (for UV and Vis)

^c Default value for doubling of process over 10° C

^d Default WASP values

^e Schnoor, 1996.

^f Molecular Dispersion, $\frac{22 \times 10^{-5}}{MW^{2/3}} \text{ cm}^2/\text{s}$

^g Molecular Dispersion adjusted for bioturbation

6.5. Temperature

Temperature is modeled as a time function, varying from month to month throughout the year. The segments vary corresponding to the modeled air temperature. Ice is not modeled in the system, so temperature never drops below 0°C. Deep sediment segments remain at a constant temperature of 4°C throughout the year. The temperature time function is presented in Table 5.

Table 5. Mean Monthly Temperatures

Date	Temp [°C]
1/1	0
2/1	0
3/1	3
4/1	9
5/1	15
6/1	20
7/1	23
8/1	22
9/1	17
10/1	11
11/1	6
12/1	0

7. Initial Conditions

Initial conditions for the Sudbury River System are presented in the Appendix in Table A-3. Sensitivity to initial conditions in the water column showed that modeling results were relatively insensitive to initial conditions within the range of observed concentrations. Due to the range of observed mercury concentrations, a relatively simple approach was used to address initial concentrations. Silts were set at 2 mg/L for all water column segments except for the GMNWR, where 6 mg/L was used. Sand and particulate organic matter were set to 0 mg/L for all water column segments. The initial concentrations of MeHg were based on observed sample concentrations for the recent round of 2007 to 2008 sampling effort. The mean MeHg concentration for all sampling points and times was 0.1 ng/L, so that was used through the system. The concentrations of Hg(0) and Hg(II) were not measured directly, so Hg(0) was assumed to be negligible so that $Hg(II) = HgT - MeHg$. The average HgT for the sample locations was more variable spatially, so average concentrations for each of the sampling locations were used. For the GMNWR, all segments without sampling locations were set to 7.0 ng/L HgT, all segments between Reservoir 1 and the GMNWR (segments 8 to 23) were set to 3.0 ng/L, which was the average HgT for Reservoir 1. Segment 1 was set to be the same as Segment 2, and Segment 3 was set to be 4.0 ng/L.

For the initial sediment mercury concentrations, Hg(0) was set to 0 so that Hg(II) could be determined from HgT – MeHg. The 2003 data was used first for all mercury sediment concentrations along the Sudbury River for the first 5 cm sediment layer. There was some variability across subsequent data sets, sometimes spanning an order of magnitude difference, and for multiple samples across transects of the same segment there was similar variability. The wide range of observed sediment concentrations is not surprising given the natural variability of sediments. Therefore, professional judgment was used for determining representative values for initial conditions. For segments where there was more recently collected sediment data, specifically transects and cores, these data were used in place of the 2003 transect data. For segments with no information, a constant number was used. For the main river reach, the 5 – 10 cm sediment layers were set to 2000 μg Hg(II)/kg and 1 μg MeHg/kg; for the GMNWR the 5 – 10 cm sediment layers were set to 1500 μg Hg(II)/kg and 3 μg MeHg/kg; and for the deeper layers for Reservoirs 1 and 2 where no sediment core data exist, Hg(II) was set to 3000 $\mu\text{g}/\text{kg}$ and MeHg to 2 $\mu\text{g}/\text{kg}$ based on Frazier et al (2000). The last segment with no specific data was Segment 89, the 5 – 10 cm layer beneath water column segment 23, which was set to 4000 μg Hg(II)/kg and 2 μg MeHg/kg.

The initial sediment concentrations for the solids required moderate level of investigation and model simulation. The solids were initialized using the information provided in the SBERA, Table 2-8 (USEPA, 2008), along with some professional judgment given the descriptions of each reach (e.g., silty, cobbley). The percent solids was used to determine the porosity of the sediments along with the observed TOC to calculate the total density of the sediment layer, assuming that inorganic solids have a density of 2.65 g/ml and organic carbon comprises 30% of the total mass of organic solids, which have a density of 1.35 g/ml. From data collected for this study (TechLaw, 2009), the fraction of sand and clay is reported for different segments of Reservoir 2. These were used to divide the total inorganic solids into silts and sands. For the remainder of the system, best professional judgment was used to determine percent sands and silts. For Reservoir 1, the last segment of Reservoir 2 was used as a basis and rounded to 40% sands, 60% silts. For the Sudbury River segments from Reservoir 1 to the GMNWR, the sediments were set at 20% sands, 20% silts, and 60% cobbles. For the GMNWR, the same as Reservoir 1 was used (40% sands and 60% silts). For the deeper sediments, the 40% sands and 60% silts ratio was used. For the segments underlying Reservoirs 2 and 1, the silt fraction was slightly increased and the sands fraction slightly decreased. The solids concentration was run without mercury present and observed to see how the system responded. The Reservoir and GMNWR systems were found to be unstable, so cobbles were added to these systems as well. To do this, 20% of the total solids were added to the top layers of the Reservoirs and the GMNWR, so that cobbles were present to some degree in all segments. The model was then run for a series of 4 runs, each for 30 yrs. The final solids concentration was then imported as the new initial condition. This was repeated and each segment was observed until each sediment layer reached a psuedo-steady state. The system had burial and resuspension, but the fraction of each component, silts, sands, organic matter and cobbles remained constant. This was to ensure that the dynamics of mercury cycling and changes over time were not a function of changes in the fractions of each solid type in the sediment layer, and that the sediment layers had effectively reach a stationary state within the system

The initial conditions used in running the Sudbury River model are fully presented in Table A-3.

8. Boundaries

Incoming flow fields are modeled as having an inherent background level of mercury. This is to capture the atmospheric deposition and loading to the river from the watershed. Wet deposition ranges from 8 – 12 µg/m²/yr and dry deposition ranges from 6 – 14 µg/m²/yr. A fraction that falls onto the watershed is assumed to runoff, approximately 20% (Rudd, 1995). Given an annual precipitation rate of 100 cm/yr, with an 80% loss from deposition to tributary outlet, we can convert deposition rate to inflow water concentration of mercury. Most of the depositing mercury is divalent (97 – 99%) and the large proportion of the watershed land-use is suburban and urban, suggesting minimal methylation occurring en route, the percent methyl mercury was modeled as 1% in winter, 2% in fall and spring, and 4% in summer. The typical %MeHg in a nationwide study suggests 4% (Krabbenhoft et al., 1999). The boundary concentration conditions are presented in Table 6.

Table 6. Atmospheric Mercury Boundary Conditions

Seasonal variability of boundary concentration conditions for Hg(II) and MeHg. These values loop continuously over the course of the model run for each year for 30 years.

Date	Dry Deposition [ug/m ³ /yr]	Wet Deposition [ug/m ³ /yr]	Total Deposition [ug/m ³ /yr]	Hg(II) [ng/L]	MeHg [ng/L]
9/23	10	10	20	3.76	0.08
12/23	6	8	14	2.74	0.028
3/20	10	10	20	3.76	0.08
6/20	14	8	22	4.68	0.208

For flow coming into Reservoir 1 from Reservoir 3 (Reservoir 3 not being impacted by historical Nyanza discharges), the concentrations in the inflow were assumed to be lower than that coming directly into the Sudbury River from tributaries. This is to account for the losses that would occur in this upstream reservoir. For this boundary, a factor of 0.3 for Hg(II) and a factor of 0.2 for MeHg was used to calibrate the inflowing concentration to the concentrations in Segment 6 (just downstream of Reservoir 3 in Reservoir 1).

Solids concentrations in the system are modeled using boundary conditions on inflows along with mercury concentrations. These are held constant throughout the year, since no clear pattern of seasonality was demonstrated from the measurements over the course of the study. The measurements over the study were averaged and applied to the applicable inflow boundary using observations of TSS, TOC, and DOC. Biotic solids were determined as TOC-DOC. Abiotic solids (modeled as silts) were determined as TSS – biotic solids. Biotic solids were modeled as inert solids with no production or decay, since concentrations

were small and transport was generally fast (this could be updated to model biotic solids with growth and decay, but may impose additional uncertainty and may not be necessary). Solids boundary conditions are presented in

Table 7.

Table 7. Solids Boundary Conditions

Actual averages of observed samples are presented in bold, remaining numbers are estimated predictions roughly interpolated as being between the measured values.

Segment	Description	TSS [mg/L]	DOC [mg/L]	TOC [mg/L]	biotics [mg/L]	silts [mg/L]
1	Upstream_Res_2	2.88	6.7	7.1	0.40	2.40
2	Reservoir_2_first_leg	2.28	6.66	7.14	0.49	1.91
5	Res2end	1.91	5.93	6.24	0.31	1.59
6	Res1from3	2.20	4.77	4.94	0.17	1.83
13	SudburyRiverReach13	2.16	5.20	5.40	0.20	1.80
24	UpofGMNWR	5.4	5.20	5.40	0.20	4.30
25	GMNWR1	5.16	5.37	5.63	0.26	3.89
26	GMNWR2	4.67	5.57	5.96	0.39	7.08
27	GMNWR3	8.50	5.50	6.00	0.50	6.50
28	GMNWR4	7.80	5.42	5.73	0.32	5.38
29	GMNWR5	6.46	5.5	5.7	0.20	5.80
30	GMNWR6	6.96	5.5	5.7	0.20	5.80
31	GMNWR7	6.96	5.5	5.7	0.20	5.80
32	GMNWR8	6.96	5.5	5.7	0.20	5.80
33	GMNWR9	6.96	5.5	5.7	0.20	5.80

9. Modeling Results

A final model for mercury within the Sudbury River system was attained by running a series of different scenarios to compare to observed values and to provide mechanistic inference on how mercury is behaving within the Sudbury River. All scenarios use the same physical layout and construct of the modeling system and also use the same solids cycling module. There are no differences in the scenarios for the flow fields or solids concentrations, the settling, resuspension, advection, and dispersion all act the same for all scenarios. The differences between the scenarios are in the mercury cycling parameterization, including boundary concentration conditions and initial concentration conditions.

The first scenario for modeling was titled Scenario 1, and named the “Base Case”, so named because it is the basis for which all the later modeling scenarios are compared. Scenario 1, “Base Case,” assumes that all mercury present in the system behaves the same, with the same transformation rate constants for Hg(II), MeHg and Hg(0) and partition coefficients for Hg(II) and Hg(0). The initial and boundary concentration conditions are both established and discussed previously in Sections 7 and 8.

The second scenario was titled Scenario 2, and it was separated into two different modeling cases (Case 1 and Case 2). The purpose of these two cases within one scenario was to decoupling the previous model structure. Scenario 2, Case 1 is determined solely by modeling the incoming flow of mercury from atmospheric (watershed) sources. In this case, titled Case 1: “Clean Sediment Case,” the initial concentrations in all media (i.e., water and sediments) are set to zero. This thereby sets the entire system to be effectively “clean” from mercury until the simulation is turned on and runs. The only mercury coming into the system is via the incoming flow concentrations at the boundaries. For this case, the parameterization of the system (i.e., mercury transformation rates and partition coefficients) is defined as for Scenario 1, Base Case. Scenario 2, Case 1, “Clean Sediment Case” therefore represents how the concentrations in the Sudbury River system would be if there were never a Nyanza site or if all traces of Nyanza contamination were removed.

The next case in this scenario is titled Scenario 2, Case 2: “Contaminated Sediment Case.” Here, the initial concentrations of the sediment and water column were set to observed concentrations (inclusive of residual Nyanza mercury), thereby the sediments are contaminated with mercury before the model is turned on and run. A significant difference from the other Scenarios, is that the inflowing water concentrations were set to zero. Therefore, clean water is assumed to come into the system.

What also distinguishes Scenario 2, Case 2 from Scenario 1 is that the mercury in this system behaves differently than the mercury in Scenario 2, Case 1. Recent research in the mercury field as well as in the organic contaminant field have suggested a difference between “new” mercury or “old” or “legacy” mercury (Hintelmann, 2002; Harris et al., 2007). The theory is that mercury partitions kinetically, taking appreciable periods of time to reach equilibrium with a solid phase. Therefore, mercury that has been in the system for a long enough time may become more strongly bound. A possible explanation for this is that mercury can penetrate into the interstices of solid particles, where it is unavailable for methylation or other processes. To account for this difference for “old” mercury, which in this study is the Nyanza-related mercury, Scenario 2, Case 2, the “Contaminated Sediment Case,” there are three different parameterizations set up and run. To account for the increased partition coefficient the K_d used in Case 1 is multiplied by either 100 (Case 2A and 2B) or 200 (Case 2C). These numbers were not chosen arbitrarily, rather based on a study done on PAHs and silts/clays found that strongly sorbed PAHs had K_d ’s 150 times greater than the slower sorbed PAHs (Ghosh et al., 2001). Metal partition coefficients compiled by Allison and Allison (2000) showed that mercury partition coefficients to sediment ranged from 6,300 – 1,000,000 L/kg with a mean of 80,000 L/kg, spanning more than two orders of magnitude. Data from another superfund site showed partition coefficients in the sediments to be upwards of 12,000,000 L/kg. To account for the more strongly sorbed mercury being less available for methylation, only a fraction of sorbed mercury could be methylated. The fractions were Case 2A: 10%, Case 2B: 1%, and Case 2C 0.5%. The decreased availability for methylation was Hintelmann et al. (2000) suggested the decreased availability for methylation when he reported methylation rates for old mercury to be 10 – 100 times lower than new mercury.

A summary of the scenarios is provided in Table 8.

Table 8. Summary of Scenario Breakdown

Scenario	Case	K_d for Hg(II) to silt	Fraction silt-sorbed Hg(II) available for methylation	Methylation rates	Hg Initial Conditions	Hg Boundary Conditions
1 “Base Case”	--	Table 2	100%	Table 3	Section 7	Table 6
2	1 “Clean Case”	as Base Case	as Base Case	as Base Case	Sediments set to 0	as Base Case
	2 “Contaminated Case”					
	2A	100xbase	10%	as Base Case	Section 7	Set to 0
	2B	100xbase	1%	as Base Case	Section 7	Set to 0
	2C	200xbase	0.5%	as Base Case	Section 7	Set to 0

9.1. Scenario 1: Base Case Modeling

The first figures (Figure 8 - Figure 11) show the model predictions for the Base Case scenario. From this modeling run, for all species of mercury, the model-predicted results exceed the observed concentrations. The unfiltered mercury concentrations predicted by the model are not only much greater than observed, but much greater than one would generally expect. In the reservoirs, concentrations in the 200 to 300 ng/L are almost two orders of magnitude higher than the observed concentrations. In the floodplain, the concentrations are 10 to 70 ng/L, about an order of magnitude higher than observed. The filtered total mercury predicted concentrations are similarly orders of magnitude higher than the observed in all locations. The only location that is not greatly overpredicted for total Hg is the first segment of Reservoir 2. This segment is primarily impacted by the inflowing concentrations. The results for filtered and unfiltered MeHg are also presented, and follow similar patterns, but not to as great a degree. The conclusion from this simulation is that it does not appear that modeling the entire system with one uniform partition coefficient adequately represents the system.

This mechanistic modeling evaluation suggests that the mercury that has been present in the system for decades from the Nyanza site has had enough time to penetrate into the interstices of the solid particles (namely silts and fines), and therefore has become effectively sequestered from the microbial active zones for methylation. Therefore, the next step included separating the

different types of mercury and simulating them individually and then combining the simulation results.

9.2. Scenario 2: Decoupling the Initial Conditions and Inflow Concentrations

The results for these runs were first presented individually on Figure 12 - Figure 15. These results reveal how well the observed measurements are modeled by either solely Case 1 or one of the Case 2s (2A, 2B, or 2C). In regard to the unfiltered HgT, the different case models do better or worse depending on the section of the Sudbury River being evaluated. For Reservoir 2, Case 1 simulates the observed concentrations better than any of the Case 2s. This is true for the filtered HgT as well. This suggests that the total mercury present in the surface water of Reservoir 2 is strongly influenced by the incoming flow concentrations. Case 1 also suggests that the HgT decreases along the length of Reservoir 2, while the Case 2s show an increase in HgT. The observed data more accurately reflect a loss in concentration along the length of the reservoir. Continuing with HgT, all model results are seen as overpredicting for the upper lobe of Reservoir 1 (the part receiving inflow from Reservoir 3), and slightly underpredicting for the part of Reservoir 1, right before the impoundment. This is more so the case for the filtered HgT for the upper lobe of Reservoir 1, where the model is more appreciably overpredicting. Right before the impoundment for Reservoir 1, the contaminated sediment cases are appreciably overpredicting both filtered and unfiltered HgT, while Case 1 does a reasonable job for the filtered HgT and slightly underpredicts a few observations for the unfiltered HgT. For the Great Meadows National Wildlife Refuge (GMNWR), all models underpredict the observed HgT for the three locations measured. There are some appreciably high unfiltered HgT observations, 10 – 30 ng/L, which the models here are incapable of predicting. From these simulations, however, it seems that the sediment here may be more actively interacting with the overlying water than the reservoir systems. For the unfiltered HgT, it is difficult to argue whether Case 1 or the Case 2s do a better job of predicting the unfiltered HgT in these systems. All of them capture some of the variability in the observations, and the results seem to lie between the two cases.

Next is to look at the MeHg model predictions and observations. For Reservoir 2, Case 1 captures relatively well the pattern observed for unfiltered MeHg, but does not capture the higher observed concentrations. The pattern of decreasing unfiltered MeHg concentrations is mimicked in the modeling simulations for Case 1. The Case 2s show an increase in MeHg concentration as the model simulates the length of Reservoir 2. The Case 2 also show a shifted peak from Case 1. The higher availability of methylation in Case 2C suggests higher concentrations of MeHg than observed, suggesting that this level of methylation may not adequately represent this system. In Reservoir 1, Case 1 seems to underpredict the MeHg concentrations, both as filtered and unfiltered. The Case 2s seem to similarly underpredict the observations; with the higher methylation rate process for Case 2C captures the highs reached in this system. In the GMNWR, the observations are higher than Case 1 and are on par with some of the Case 2 results. This suggests that the influence of the sediment may be more important further downstream such as GMNWR.

After investigating these cases as individual mechanistic models, the next step was to add the results of the two systems. These results are presented in Figure 16 - Figure 19. That is to have a Base Case clean scenario as one case, and then have cases where the simulated concentrations of the Case 2s were added to the Case 1 results, thereby incorporating both the incoming inflow concentrations and the contaminated sediment concentrations. This assumes that the results are linear and may be added together, or rather, more accurately, that the errors introduced by linearly adding the two results are small enough as to not greatly interfere with interpretation of the results.

Starting again with HgT, adding the Case 2s to Case 1, the first section of Reservoir 2 seems to be relatively well modeled by any of the combinations. With Case 1 effectively capturing the observations in this segment, and Case 2s being near zero, it would be adequate to use any model to represent this system. For unfiltered HgT in this segment, the results seem to be slightly overpredicting, this may be a result of some error in simulating solids in these systems, due to limited information on solids in the Sudbury River and Reservoir 2. For the downstream segments of Reservoir 2, the addition of the Case 2s overwhelm the model and greatly overpredict in these cases. This suggests that for HgT, both filtered and unfiltered, the Case 1 + Case 2s overpredict for Reservoir 2. The model simulates the observed concentrations well enough with no sediment interaction. For Reservoir 1, the upper lobe (near Reservoir 3), is overpredicted by the combined cases, and Case 1 does well enough without the addition of Case 2s. For the end of Reservoir 2, Case 1 does a better case than the addition of the Case 2s. For the GMNWR, all cases underpredict the high observations. These observations may be artificially inflated by inadvertently capturing sediment suspended when trying to take a sample or may represent higher interaction with the sediment than the model is capturing. Another factor (source of uncertainty) is that the model is simulating the entire width of the GMNWR as a single segment, therefore the model is effectively integrating the channel with the floodplain, so the high peaks may be reflective of the floodplain, but not the cross-sectional average that the model is simulating. For the filtered HgT, all the cases do similarly well for the GMNWR. It is therefore hard to separate which model does best for this case, but demonstrates that all the models here are acceptable.

For MeHg, the combination of models all underpredict both filtered and unfiltered MeHg in the upstream of Reservoir 2. Moving downstream the Case 2s suggest an increase in MeHg concentration going downstream, which is not necessarily reflected in the observations. The higher peaks of MeHg are better captured by Case 2C, but this case seems to overpredict for the other observations, Case 2A and 2B predict an increase in MeHg when the observations suggest a drop in concentration. For Reservoir 1, the upper lobe underpredicts both filtered and unfiltered. Case 2C has higher concentrations predicted, but the peaks are at times that observations suggest a drop rather than an increase. The sharp fluctuations of Case 2C, though, would require more temporally resolved observations to rule out the high fluctuations predicted. For the GMNWR, the models all underpredict the observations. Case 2C comes close to capturing the peaks, but again has sharp fluctuations that are temporally sharp and not reflected in the observations. It is possible, however, the Case 2C may reflect the better simulation than the other cases. This would then suggest that there is an appreciable influence of the sediments in this case, which is different than the Reservoir 2 where Case 1 adequately reflects the system.

9.3. Scenario 3: Doubled Methylation Rate Constants

One issue that arises from these simulations is that along with increasing the partition coefficient, the fraction available for methylation is altered. A question then arises to whether what is more important: the methylation rate constant, which is impacted by the fraction available for methylation, or the partition coefficient itself. To delve into these issues, a simple sensitivity to methylation rate constant was investigated. To do this, all the cases, Case 1, 2A, 2B, and 2C were all run with all methylation rate constants doubled, giving case 3, 3A, 3B, and 3C. These results are presented in the next set of figures, Figure 20 - Figure 23. The change in methylation rate constants has little effect on the filtered and unfiltered HgT, so we can look directly at the MeHg results. The increased methylation rate constant only slightly affects the upstream of Reservoir 2, but increases the MeHg concentrations in the other reaches more appreciably. Again, the clean sediment case adequately represents Reservoir 2, with the combination of clean and contaminated sediment cases results in overpredictions of MeHg, both filtered and unfiltered, with the largest impact with Case 3C. For Reservoir 1, Case 3C may capture the spikes of MeHg, both unfiltered and filtered, in both sections of Reservoir 1. For the GMNWR, the increased methylation rate constants improve the simulation of filtered and unfiltered MeHg. For the GMNWR, it seems that to capture the MeHg concentrations, the contaminated sediment case is required.

10. The Final Model

Based on the modeled different scenarios, a final overall model was designed. For this model, the combination of the clean case, with incoming mercury concentrations with clean sediments, and the contaminated case, with historically-contaminated sediments and clean (zero concentrations of HgT) inflow, was used. The partition coefficients Hg(II) to silt was modeled as being 100 times larger than the clean case, and only 1% of sorbed Hg(II) was available for methylation, for the contaminated case. Finally, higher methylation rate constants were used in the GMNWR.

10.1. Final Model Results and Comparisons

The results of the final model are presented in Figures 24 – 27. Additionally, observed versus predicted plots are presented in Figures 28 – 31. These plots take the average of all concentrations of each mercury species (HgT and MeHg, each filtered and unfiltered) for each sampling location. The calculated average takes all samples throughout the year ($n = 7$, except for the most downstream sample in the GMNWR, where $n = 6$) and takes the mean and plots the mean and standard deviation. The model predicted values are taken from the same time and WASP surface water segment, and these are similarly averaged. These figures permit the comparison of the means and the variability in both the model results and the observed results.

The final model generally over-predicted HgT, both filtered and unfiltered, in Reservoir 2. The model did generally well for unfiltered HgT in Reservoir 1, and did not capture the spikes for unfiltered HgT in the GMNWR. The samples in GMNWR for HgT may have included some disturbed sediment, so it is feasible that these values would necessarily be under-predicted. The model did generally well for filtered HgT, with a general under-prediction. For MeHg, the model

generally did well, but did not fully capture the wide range of observed MeHg concentrations for filtered and unfiltered.

10.2. 30-Year Predictions

The final model was run for 30 years to predict mercury concentrations for the Sudbury River if the system were to continue in its present state. The two-year mean was calculated for all WASP segments within a given reach. For example, all predicted concentrations in segments 1 – 5 for two years were averaged. The results are presented solely as dissolved MeHg concentration in Figure 32 and for fish tissue concentration (using a site-specific BAF of 7.8×10^6 L/kg, as detailed in Appendix B. BAF determination) in Figure 33. The results are for simulation time periods of 30 yrs. For the dissolved MeHg, the results are for years 1 – 30, while for the fish tissue concentration, the yrs are 4 – 33. The lag in fish tissue concentrations incorporates the delay of fish tissue concentration due to transfer up the food chain, such that a given 4-year old fish is expressing mercury exposure for the past 4 years of its life.

11. Areas of Uncertainty with the Final Model

All environmental models are simplifications of complex systems, and therefore will never exactly predict observations. It is therefore important to understand the uncertainty in a given model and to understand where its biases may be (USEPA, 2009). The deviations from observations are presented in previous figures. In this section, some of the areas of uncertainty are presented.

Some areas of uncertainty are intrinsic to model representation itself. WASP models each segment as a well-mixed volume. For both the water column and the sediments, the WASP model has a well-mixed and uniform concentration throughout the segment. This averaging throughout the volume is a necessary simplification, and must be realized that the spatial variability is averaged across the system. This also results in some level of numerical dispersion across the linear distance as well as instant mixing within deep segments. Additionally, the model only allows for three solids types, which is more rigorous than some models but less rigorous than others. This results in uncertainty in the importance of a larger range of particle sizes than incorporated in the actual model framework.

The flood plains were modeled as one segment of a given shape. This leads to issues with the fact that the channel will flow faster and have erosional properties. These observations may be artificially inflated by capturing sediment suspended when trying to take a sample, or may represent higher interaction with the sediment than the model is capturing. Another factor is that the model is simulating the entire width of the GMNWR as a single segment, therefore the model is effectively integrating the channel with the floodplain, so the high peaks may be reflective of the floodplain, but not the cross-sectional average that the model is simulating.

The extent of influence of groundwater in the system is unknown. Currently the model assumes that there is no groundwater interaction with the surface water (*i.e.*, that the Sudbury river is neither a gaining nor a losing stream). If there are reaches in the Sudbury River that are losing,

then there may be an additional loss of mercury from the system as the water carries dissolved mercury of all forms into the sediments, and could effectively pass through the sediment and out of the model domain, further decreasing mercury concentrations in the simulated sediment layers. Conversely, if there are reaches where the Sudbury River is gaining, then there could be additional loading of mercury concentrations as the pore water mercury is carried into the overlying water column. This would result in an increased impact of the sediment pore water mercury concentrations of both Hg(II) and MeHg.

A two-year hydrologic cycle of data was used in the model, which was used to drive the hydrodynamics of the WASP model. These two years were then repeated to provide 32 years of hydrologic inputs. On a couple of dates during the records used there was significant rainfall events. On September 7, 2008, there was enough rain to qualify as a 10-year storm event and on April 16, 2007 there was 4 inches of rain, equivalent to a 5-year storm event. As a result of repeating the hydrologic inputs, these events were repeated so that they occurred 16 times throughout the simulation. There is therefore some uncertainty attributable to inclusion of rainfall events at a significantly greater frequency than would be expected to occur for the duration of the simulation (*i.e.*, 16 ten-year storms over 32 years as opposed to 3 or 4). These events may project an increase in erosion and transport and thus an increase in the interaction between the sediments and the overlying water column. This could result in the results being biased high and thus long-term (predicted) MeHg concentrations being higher than actually observed due to limited burial and increased transport.

The full extent of the influence of the boundary concentrations, representing the influence of atmospheric deposition and watershed loading to the Sudbury River, is uncertain. If these influences are under-represented (Hg(II) and MeHg boundary conditions are too low), then the concentrations of MeHg in the river would be greater than predicted, and the influence of remedial strategies would be reduced due to possible recontamination from other non-point and/or background sources. However, if these are over-represented in the model (Hg(II) and MeHg boundary conditions are higher than actual), then the ability of the remedial strategies to reduce mercury concentration in fish would be greater than simulated here (*i.e.*, there would be greater reductions in fish tissue Hg concentrations than simulated).

The rate constants of mercury methylation within the GMNWR have an important influence on the simulated concentrations of MeHg in this reach. Wetlands are described by a different hydrology than rivers or lakes, and they have received substantial research and observation with respect to methylation of mercury. Certain characteristics of wetlands, such as: seasonal flooding, increased residence times, increased organic matter and carbon mineralization, and zones of anoxia result in an environment where methylation potential is high (St. Louis et al., 1994; Hurley et al., 1995; Krabbenhoft et al., 1999; Kelly et al., 1995; Kelly et al., 1997; Brigham et al., 2009). Mercury from all sources will be methylated at a higher rate in wetlands than in other aquatic systems, resulting in higher methylmercury concentrations at the base of the food web that increases the mercury burden to fish. These observations are born out in the recent evaluation of the GMNWR (Reach 8) of the Sudbury River for this modeling effort. As evidenced by the observations in the recent measurements of MeHg and dissolved MeHg in surface water along the Sudbury River, the MeHg concentrations increase as they travel through the GMNWR. This was also observed by Waldron, *et al* (2000). The model incorporates these processes and reflect the

current observed mercury concentrations. If, however, the model has methylation rate constants that are higher than actual, then the simulated MeHg concentrations may be over-estimated, thus the observed fish tissue concentrations (over time) would be less than predicted. Conversely, if methylation rate constants are higher than used in the model, then the simulated MeHg concentrations would be under-predicted, and fish tissue mercury results would be higher than predicted.

The final model assumes that the overall structure of the Sudbury River system will remain the same as it is today. That is the hydrologic cycle, the temperature fluctuation, watershed loading and atmospheric deposition, the water chemistry, and food web will all remain the same in 30 years as it is today. This assumption is necessary to predict forward, but there may be changes within the system that are unknown and produces a corresponding amount of uncertainty.

References

- Allison, J.D., Allison, T.L. 2000. Partition Coefficients for Metals in Surface Water, Soil, and Waste. Internal USEPA Report.
- Amyot, M., Lean, D.R.S., Poissant, L., Doyon, M.-R. 2000. Distribution and transformation of elemental mercury in the St. Lawrence River and Lake Ontario. Canadian Journal of Fisheries and Aquatic Sciences 57(Suppl 1):155–163.
- Benoit, J.M., Gilmour, C.C., Heyes, A., Mason, R.P., Miller, C. 2003. Geochemical and biological controls over methylmercury production and degradation in aquatic systems. ACS Symposium Series 835: 262–297.
- Brumbaugh, W.G., Krabbenhoft, D.P., Helsel, D.R., Wiener, J.G., Echols, K.R. 2001. A national pilot study of mercury contamination of aquatic ecosystems along multiple gradients: bioaccumulation in fish. USGS/BRD/BSR-2001-0009, iii+25pp.
- Eckley, C.S., Hintelmann, H. 2006. Determination of mercury methylation potentials in the water column of lakes across Canada. Science of the Total Environment 368:111–125.
- Electric Power Research Institute (EPRI). 2003. Factors Affecting the Predicted Response of Fish Mercury Concentrations to Changes in Mercury Loading: Application of the Dynamic Mercury Cycling Model to Four Lakes, EPRI, Palo Alto, CA: 2003. Product ID 1005521
- EPRI. 2002. Dynamic Mercury Cycling Model for Windows 98/NT/2000/XP™ - A Model for Mercury Cycling in Lakes. D-MCM Version 2.0. User's Guide and Technical Reference. November.
- Frazier, B.E., Wiener, J.G, Rada, R.G. Engstrom, D.R. 2000. Stratigraphy and Historic Accumulation of Mercury in Recent Depositional Sediments in the Sudbury River, Massachusetts, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences.57:1062-1072.

Gilmour, C.C., Henry, E.A. 1991. Mercury methylation in aquatic systems affected by acid deposition. *Environmental Pollution*. 71:131–169.

Ghosh, U., Talley, J.W., Luthy, R.G. 2001. Particle-Scale Investigation of PAH Desorption Kinetics and Thermodynamics from Sediment. *Environmental Science & Technology*. 35(17):3468-3475.

Harris, R.C., Rudd, J.W.M. , Amyot, M., Babiarz, C.L., Beaty, K.G., Blanchfield, P.J., Bodaly, R.A., Branfireun, B.A., Gilmour, C.C., Graydon, J.A., Heyes, A., Hintelmann, H., Hurley, J.P., Kelly, C.A., Krabbenhoft, D.P., Lindberg, S.E., Mason, R.P. Paterson, M.J., Podemski, C.L. Robinson, A., Sandlands, K.A., Southworth, G.R., St. Louis, V.L., Tate M.T. 2007. Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition. *Proceedings of the National Academy of Sciences*. 104(42): 16586-16591.

Heyes, A., Mason, R, Kim, E., Sunderland, E. 2006. Mercury methylation in estuaries: Insights from measuring rates using stable mercury isotopes. *Marine Chemistry*. 102:134–147.

Hintelmann, H., Keppel-Jones, K., Evans, R.D.. 2000. Constants of Mercury Methylation and Demethylation Rates in Sediments and Comparison of Tracer and Ambient Mercury Availability. *Environmental Toxicology & Chemistry*. 19(9):2204-2211.

Hintelmann, H., Harris, R., Heyes, A., Hurley, J.P., Kelly, C.A., Krabbenhoft, D.P., Lindberg, S. Rudd, J.W.M., Scott, K.J., St. Louis, V.L. 2002. Reactivity and Mobility of New and Old Mercury Deposition in a Boreal Forest Ecosystem during the First Year of the METAALICUS Study. *Environmental Science & Technology*. 36(23): 5034-5040.

Hudson R.J.M., Gherini, S.A., Watras, C.J., Porcella, D.B. (1994) Modeling the Biogeochemical Cycle of Mercury in Lakes: The Mercury Cycling Model (MCM) and Its Application to the MTL Study Lakes. In: *Mercury Pollution - Integration and Synthesis*. C.J. Watras and J.W. Huckabee (Eds.). CRC Press Inc. Lewis Publishers.

Kelly, C.A., Rudd, J.W.M., St. Louis V.L., Heyes, A. 1995. Is Total Mercury Concentration a Good Predictor of Methyl Mercury Concentration in Aquatic Systems? *Water Air and Soil Pollution*. 80(1-4): 715-724.

Kelly, C.A., Rudd, J.W.M., Bodaly, R.A., Roulet, N.P., St. Louis, V.L., Heyes, A., Moore, T.R., Schiff, S., Aravena, R., Scott, K.J., Dyck, B., Harris R., Warner, B., Edwards G. 1997. Increases in Fluxes of Greenhouse Gases and Methyl Mercury following Flooding of an Experimental Reservoir. *Environmental Science & Technology*. 31:1334-1344.

Knightes, C. (2008) Development and test application of a screening-level mercury fate model and tool for evaluating wildlife exposure risk for surface waters with mercury-contaminated sediments (SERAFM). *Environmental Modelling & Software* 23(4): 495-510.

Krabbenhoft, D.P., Wiener, J.G., Brumbaugh, W.G., Olson, M.L., DeWild, J.F., Sabin. T.J. 1999. A National Pilot Study of Mercury Contamination of Aquatic Ecosystems along Multiple

Gradients. U.S. Geological Survey Toxic Substances Hydrology Program – Proceedings of the technical meeting. Charleson, S.C., March 8-12, 1999. U.S.G.S. Water Resources Investigations report 99-4018B, Vol 2, p 147-160.

Lalonde, J., Amyot, M., Kraepiel, A., Morel, F. 2001. Photooxidation of Hg(0) in artificial and natural waters. *Environmental Science & Technology*. 35: 1367–1372.

Lick, W. 2008. Sediment and Contaminant Transport in Surface Waters. University of California, Santa Barbara.

Mason, R.P., Morel, F.M.M., Hemond, H.F. 1995. The role of microorganisms in elemental mercury formation in natural waters. *Water, Air, and Soil Pollution*. 80:775–787.

Matilainen, T., Verta, M. 1995. Mercury methylation and demethylation in aerobic surface waters. *Canadian Journal of Fisheries and Aquatic Sciences* 52:1597 – 1608.

Marvin-DiPasquale, M. M., Lutz, A., Brigham, M.E., Krabbenhoft, D.P., Aiken, G.R., Orem, W.H., Hall, B.D. 2009. Mercury Cycling in Stream Ecosystems. 2. Benthic Methylmercury Production and Bed Sediment-Pore Water Partitioning. *Environmental Science & Technology*. 43: 2726-2732.

O'Driscoll, N., Beauchamp, S., Siciliano, S., Rencz, A., Lean, D. 2003. Continuous analysis of dissolved gaseous mercury (DGM) and mercury flux in two freshwater lakes in Kedjimkujik Park, Nova Scotia: Evaluating mercury flux models with quantitative data. *Environmental Science & Technology*. 37:285–294.

O'Driscoll, N., Siciliano, S., Lean, D., Amyot, M. 2006. Gross photoreduction kinetics of mercury in temperate freshwater lakes and rivers: Application to a general model of DGM dynamics. *Environmental Science & Technology*. 40:837–843.

Rudd, J.W.M. 1995. Sources of Methyl Mercury to Freshwater Ecosystems: A Review. *Water, Air, and Soil Pollution*. 80: 697-713.

Schnoor, J.L. 1996. Environmental Modeling. Fate and Transport of Pollutants in Water, Air, and Soil. John Wiley & Sons, Inc. New York.

Schwab, G.O. 2005. Soil and Water Conservation Engineering. 5th edition. Thomson Learning.

Sellers, P., Kelly, C.A., Rudd, J.W.M., MacHutchon, A.R. 1996. Photodegradation of methylmercury in lakes. *Nature* 380:694–697.

Sunderland, E.M., Gobas, F.A.P.C., Heyes, A, Branfireun, B.A., Bayer, A.K., Cranston, R.E., Parsons, M.B. 2004. Speciation and bioavailability of mercury in well-mixed estuarine sediments. *Marine Chemistry*. 90:91–105.

TechLaw. 2009. Report Summarizing Data Collected for the Nyanza Mercury Modeling Effort. Submitted to the Office of Environmental Measurement and Evaluation. USEPA, Region I. North Chelmsford, MA. March 24.

Tetra Tech, Inc. 1996. Regional Mercury Cycling Model: A Model for Mercury Cycling in Lakes (R-MCM Version 1.0b Beta), Draft User's Guide and Technical Reference. Prepared for the Electric Power Research Institute and Wisconsin Department of Natural Resources. December 1996.

Tetra Tech, Inc. 1999. Everglades Mercury Cycling Model for Windows 95/NT™ - A Model for Mercury Cycling in Everglades Marsh Areas. Draft User's Guide and Technical Reference Version 1.0 Beta, June 1999

U.S. Army Corps of Engineers (ACoE). 2001. Hydrodynamic and Sediment Transport Study of Sudbury River, Massachusetts. Numerical Model Investigation. Final Report. Written by Gregory H. Nail and David D. Abraham. Coastal and Hydraulics Laboratory. U.S. Army Engineer Research and Development Center. Vicksburg, MS. ERDC/CHL TR-01-15. August.

U.S. Environmental Protection Agency (USEPA). 1997. Mercury Study Report to Congress. EPA-452/R-97-005. Final Report. U.S. Government Printing Office, Washington, DC.

USEPA. 2008. Final Supplemental Baseline Ecological Risk Assessment. Nyanza OU4 Chemical Waste Dump Superfund Site Operable Unit 4 – Sudbury River. Ashland, Massachusetts. Remedial Investigation / Feasibility Study EPA Task Order No. 0026-RI-CO-0115. Remedial Action Contract. No. EP-S1-06-03. Volume 1: Sections 1 – 5. Prepared by Nobis Engineering, Inc. and Avatar Environmental, LLC. USEPA Region 1. December.

USEPA. 2009. Understanding the Use of Models in Predicting the Effectiveness of Proposed Remedial Actions at Superfund Sediment Sites. Sediment Assessment and Monitoring Sheet #2. Office of Superfund Remediation and Technology Innovation. OSWER Directive 9200.1-96FS. November.

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press. San Diego, CA.

Wiener, J.G. and P.J. Shields. 2000. Mercury in the Sudbury River (Massachusetts, U.S.A.): Pollution History and a Synthesis of Recent Research. Canadian Journal of Fisheries and Aquatic Sciences. 57: 1062-1072.

FIGURES

Figure 1. Sudbury River Focus Area and WASP Model Segments

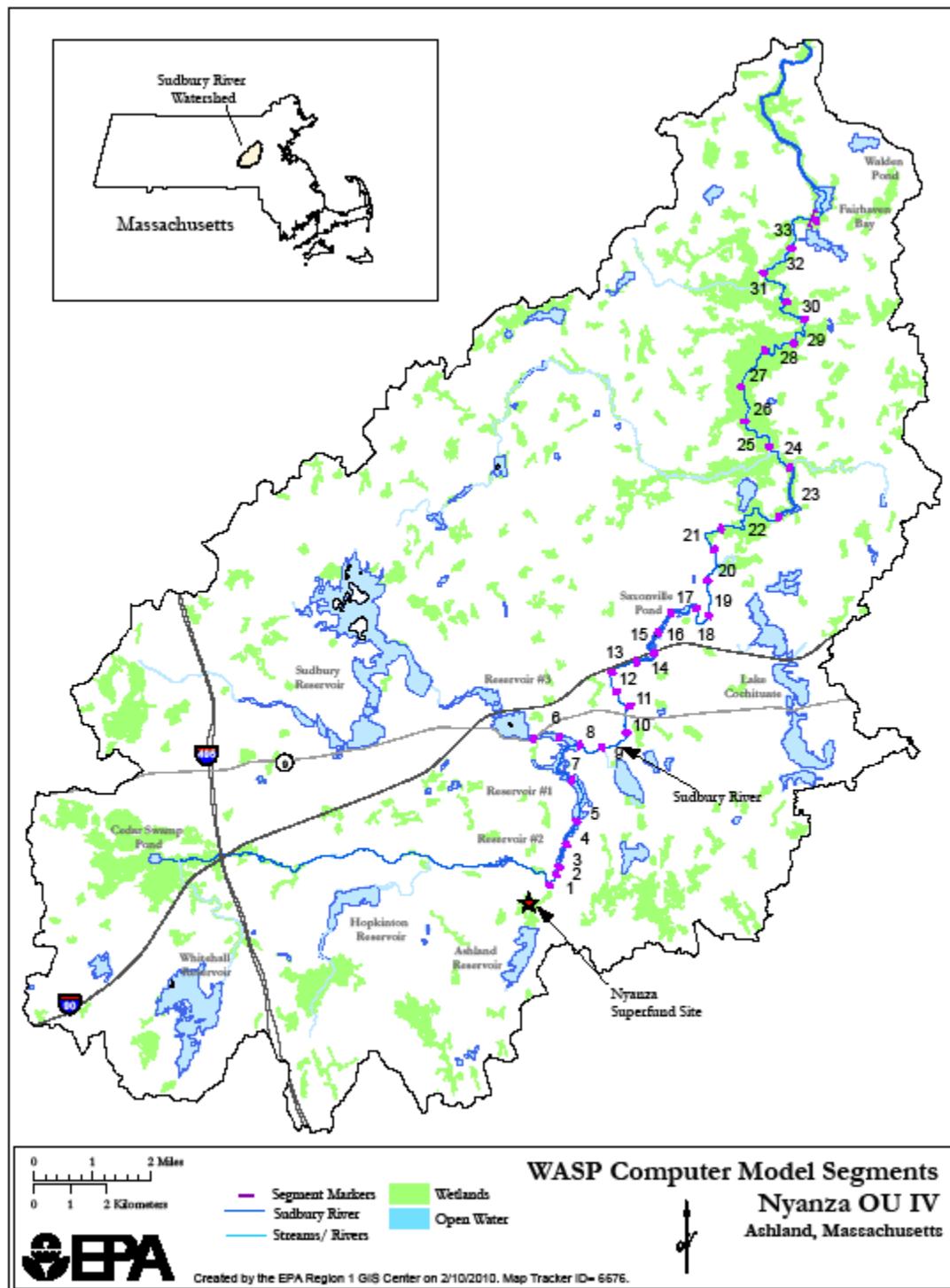


Figure 2. General Layering of WASP Segments (downstream of Reservoir 1 impoundment)

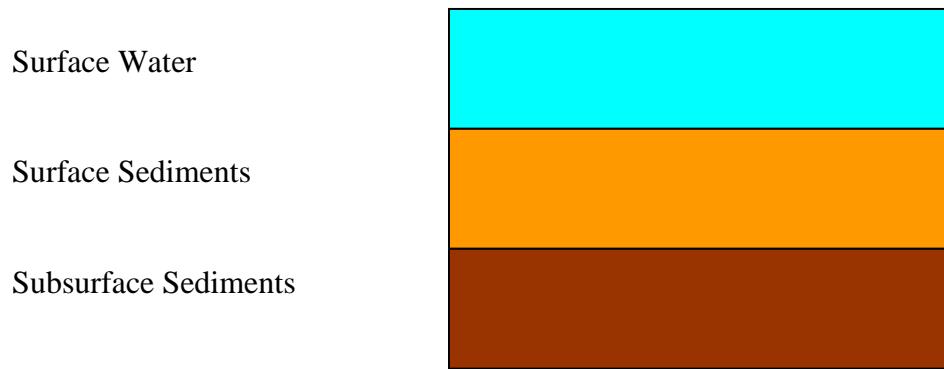


Figure 3. Layering of WASP Segments upstream of Reservoir 1 impoundment, except final segment of Reservoir 2

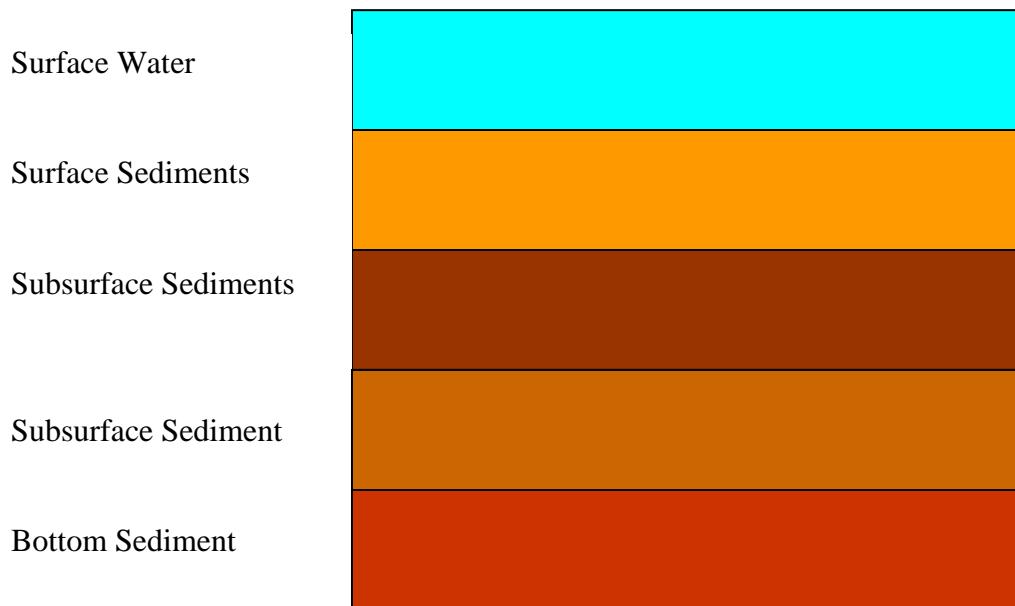


Figure 4. Layering of WASP Segments upstream of Reservoir 1 impoundment, except final segment of Reservoir

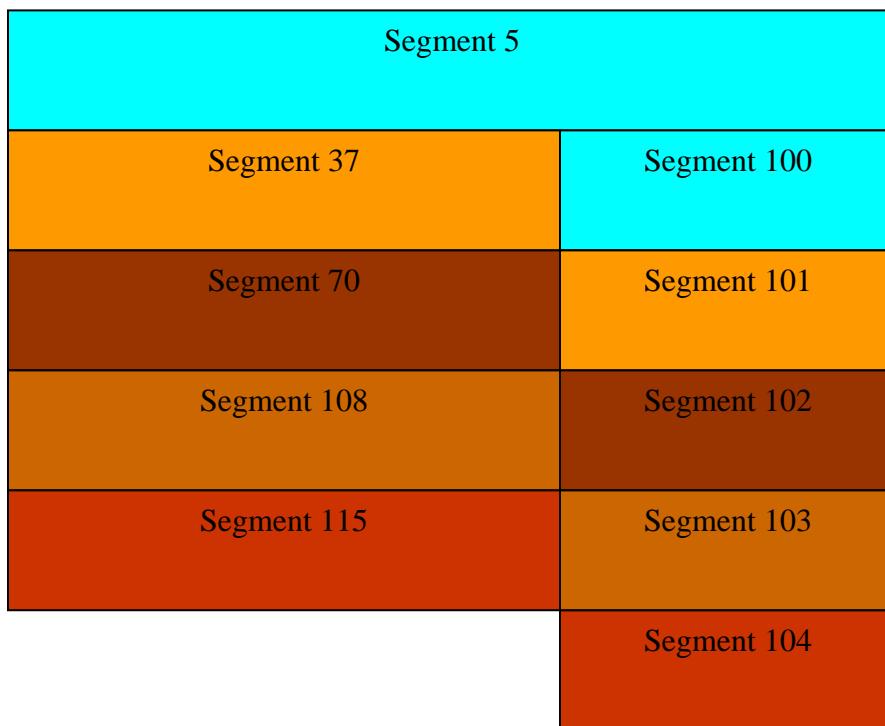


Figure 5. Representation of the processes governing solids cycling

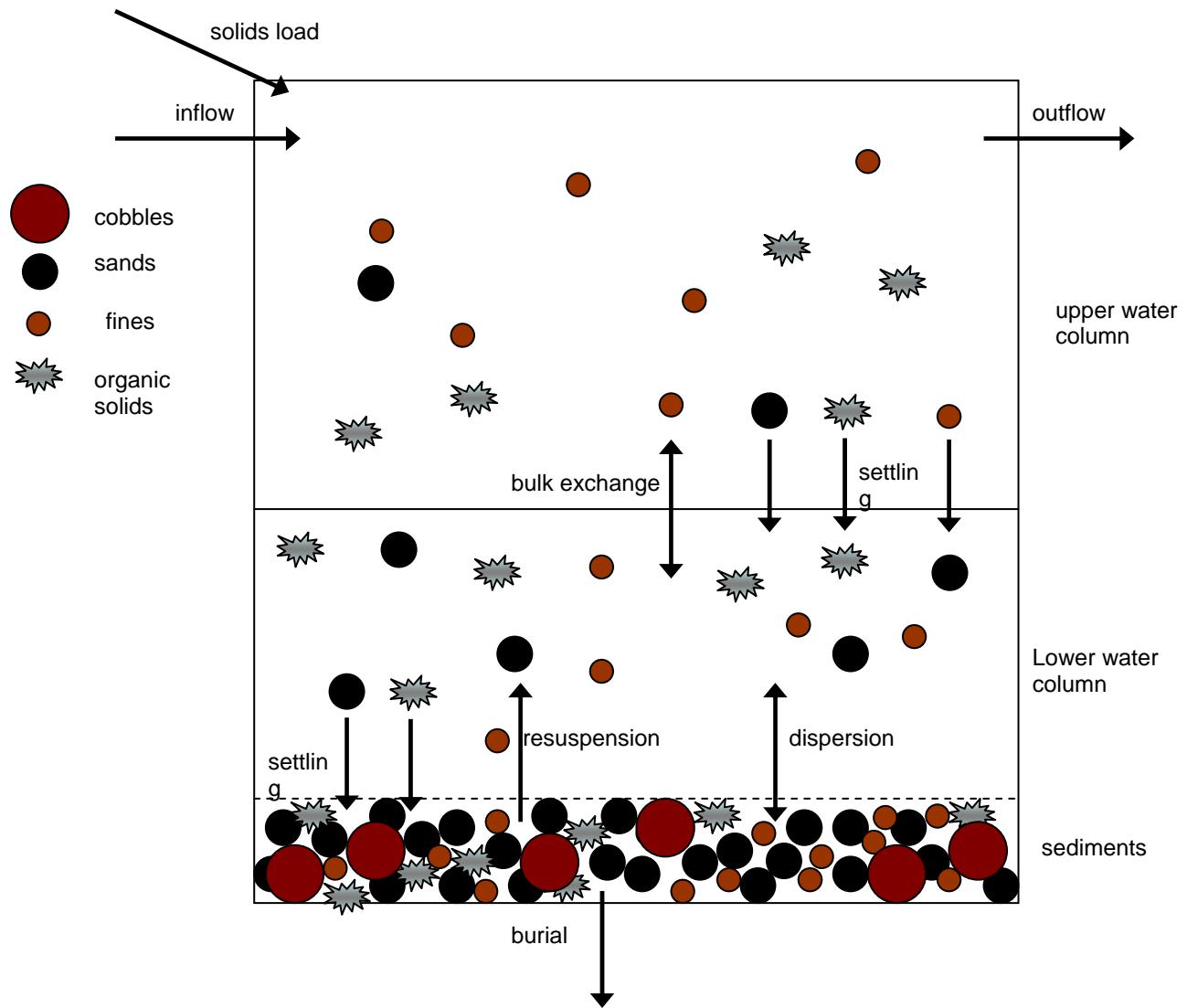


Figure 6. Equilibrium partitioning and complexation of mercury to solids and DOC

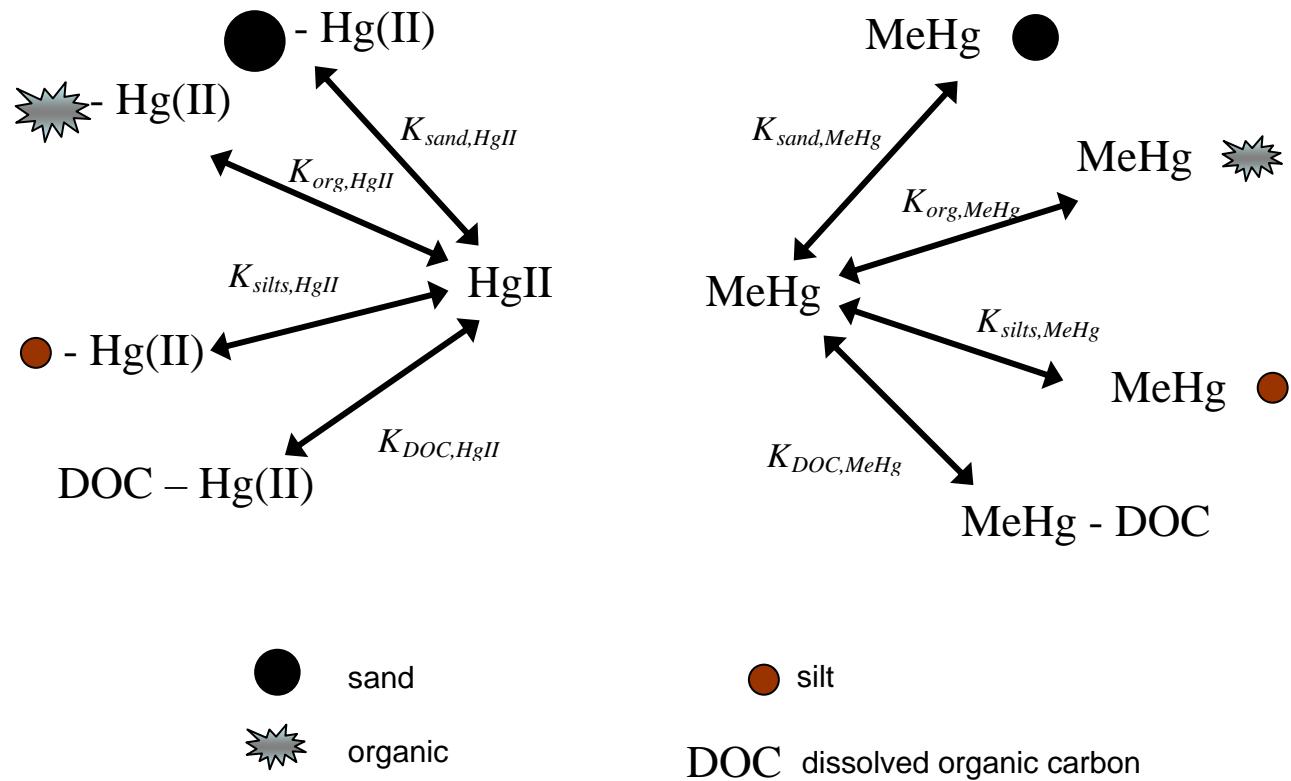


Figure 7. Representation of the processes governing mercury cycling

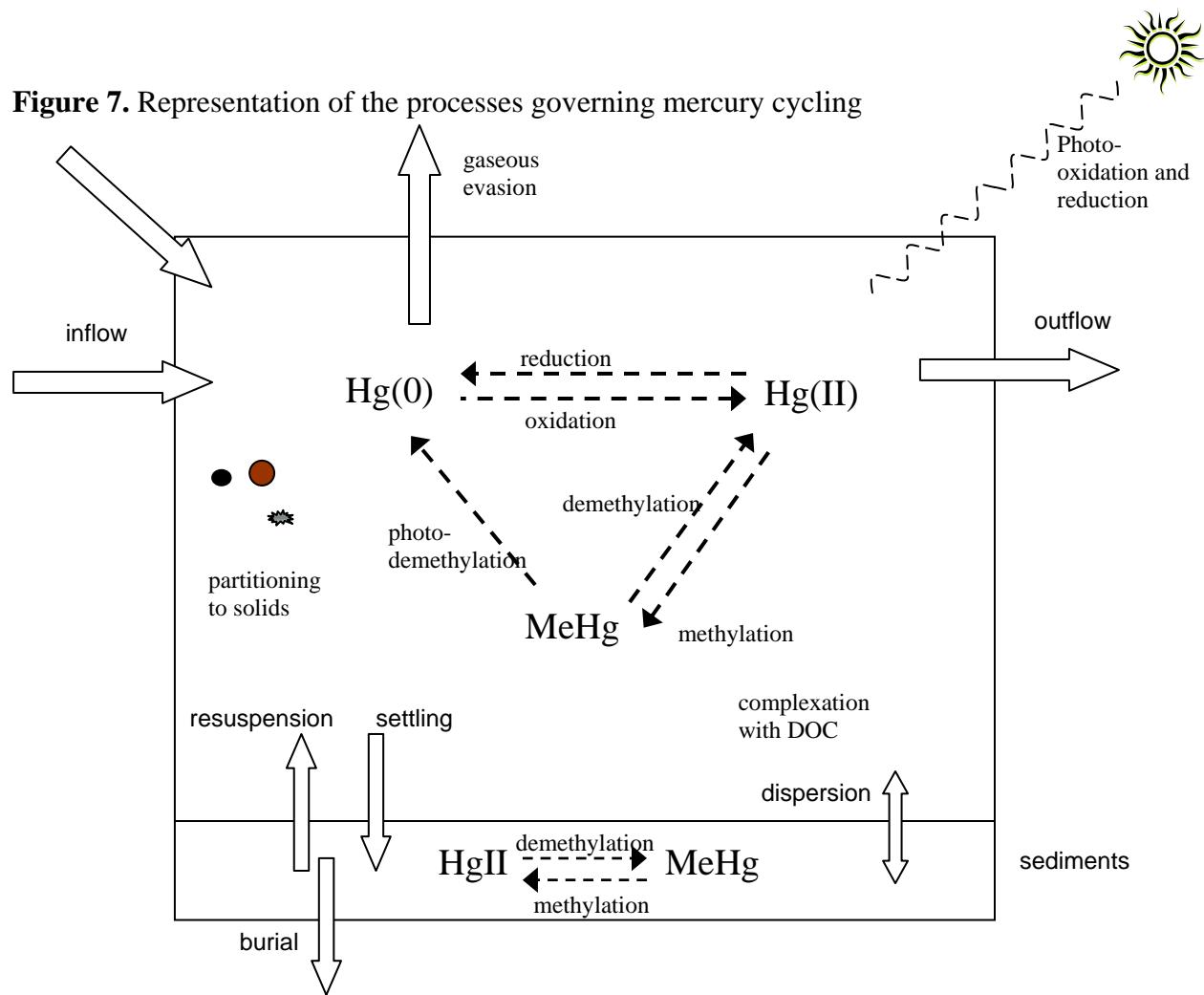


Figure 8. Base Case (Scenario 1) with current boundary conditions and contaminated sediments. Unfiltered Total Mercury Concentrations [ng/L]

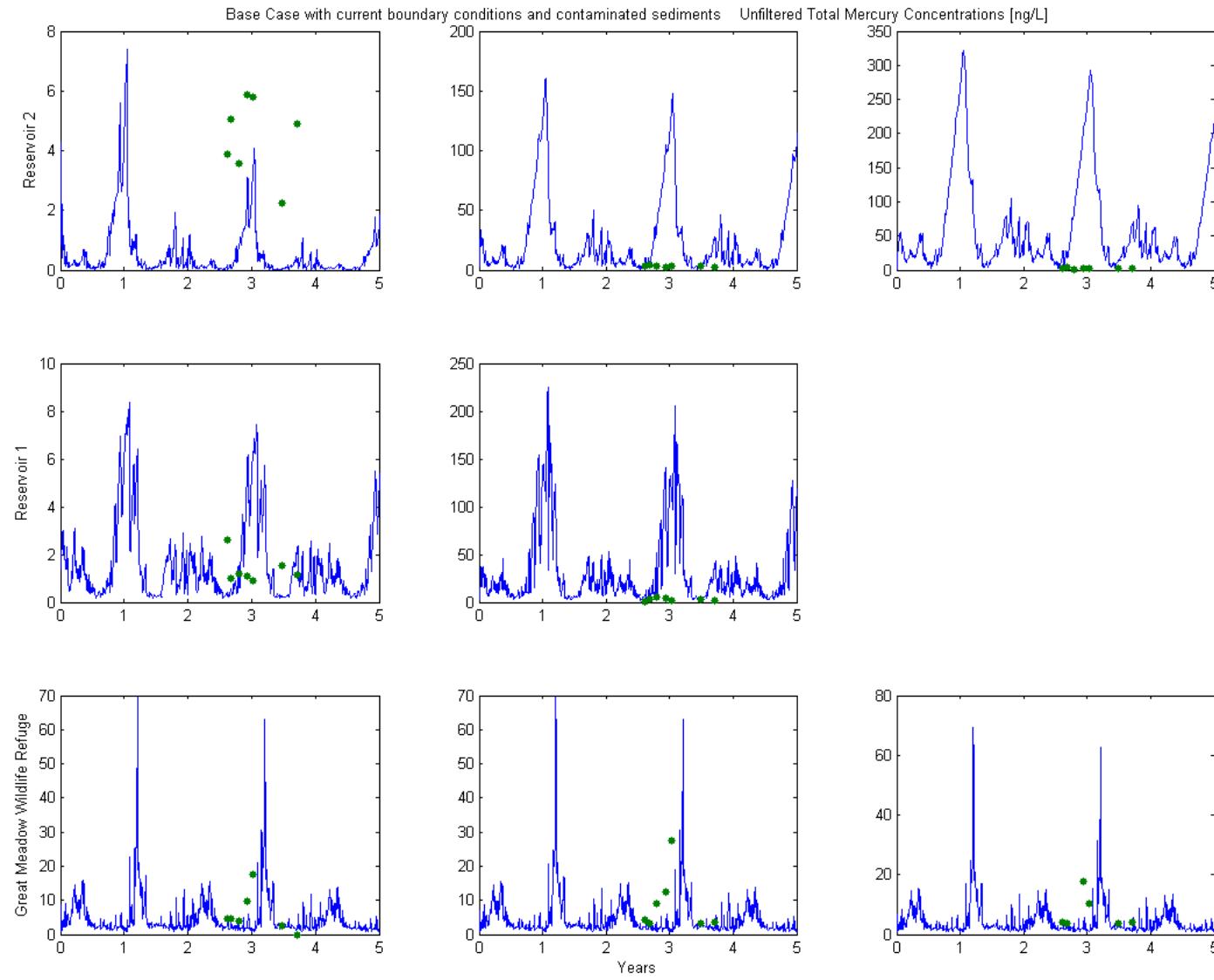


Figure 9. Base Case (Scenario 1) with boundary conditions and contaminated sediments. Unfiltered Methyl Mercury Concentrations [ng/L]

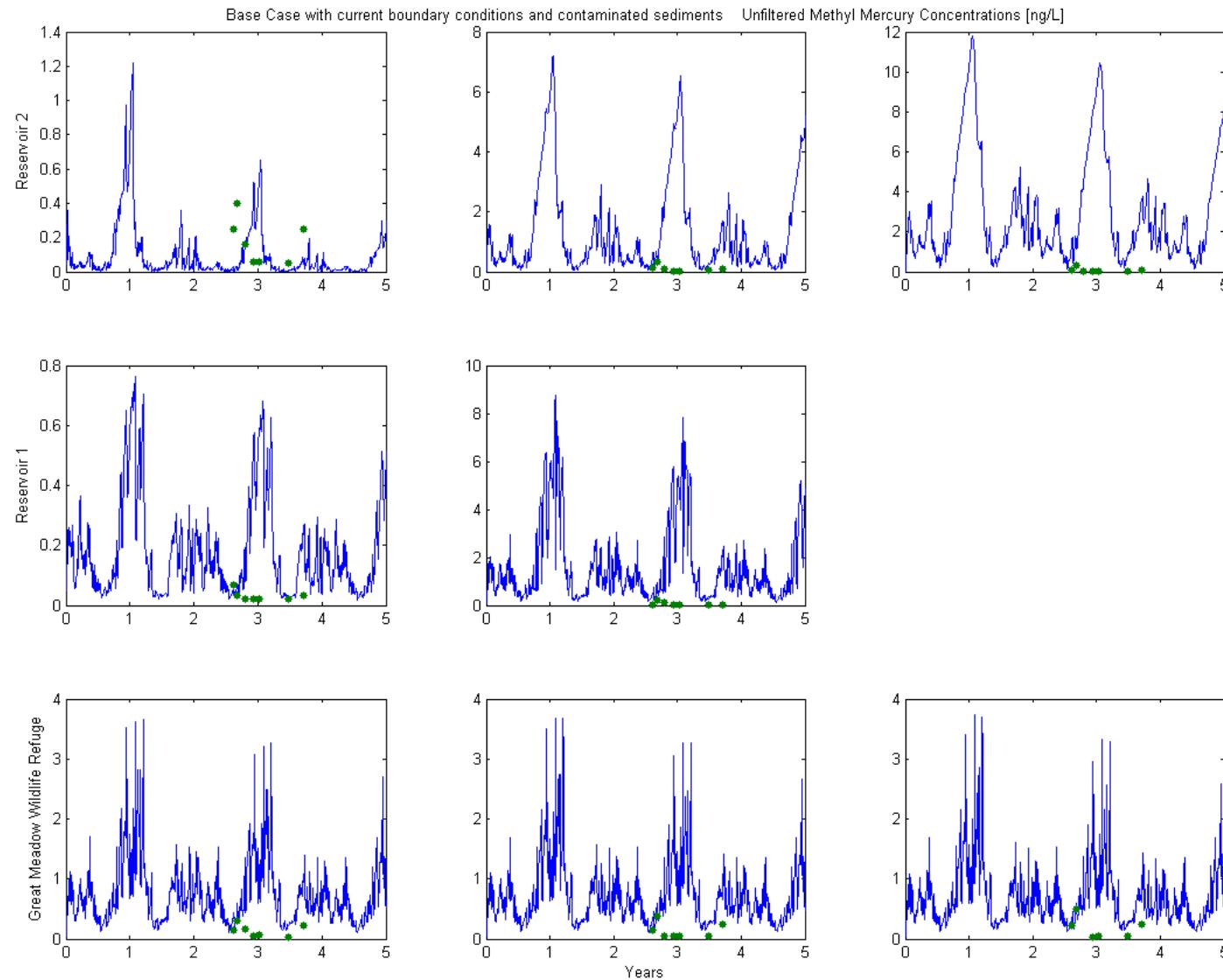


Figure 10. Base Case (Scenario 1) with boundary conditions and contaminated sediments. Filtered Total Mercury Concentrations [ng/L]

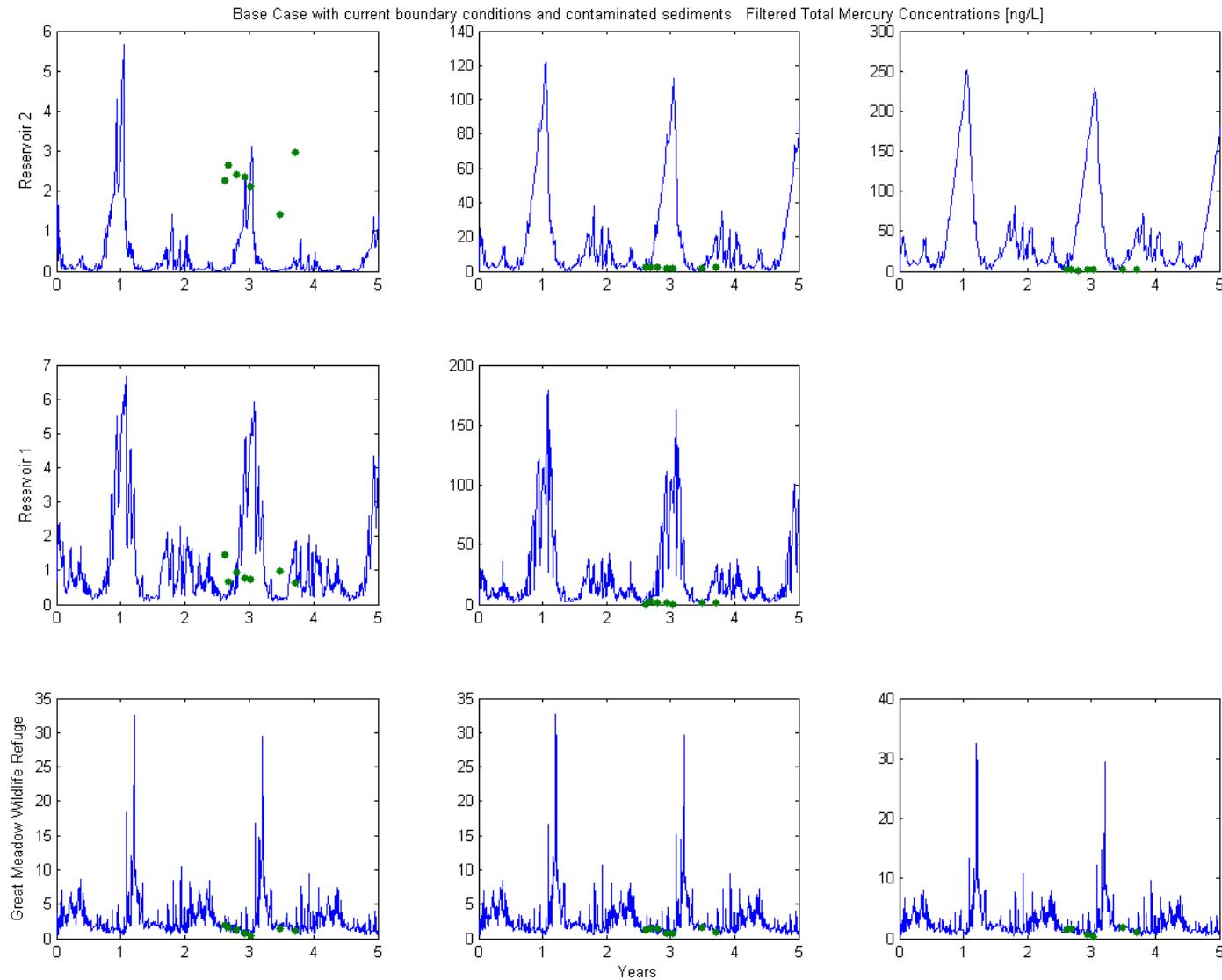


Figure 11. Base Case (Scenario 1) with boundary conditions and contaminated sediments. Filtered Methyl Mercury Concentrations [ng/L]

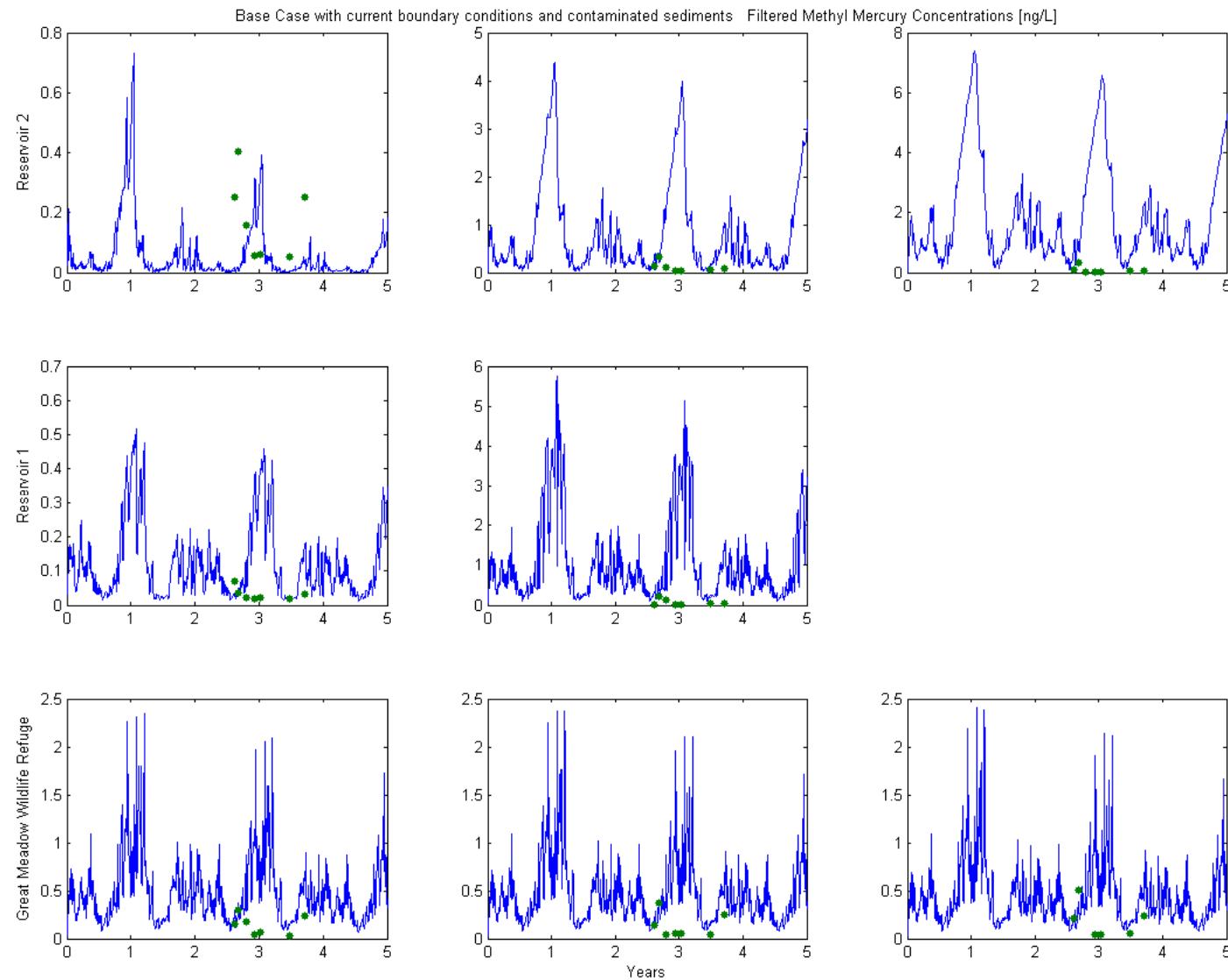


Figure 12. Scenario 2: Comparison of Clean Case (Case 1) and Contaminated Sediment Cases (Case 2A, 2B, 2C). Unfiltered Total Mercury Concentration [ng/L]

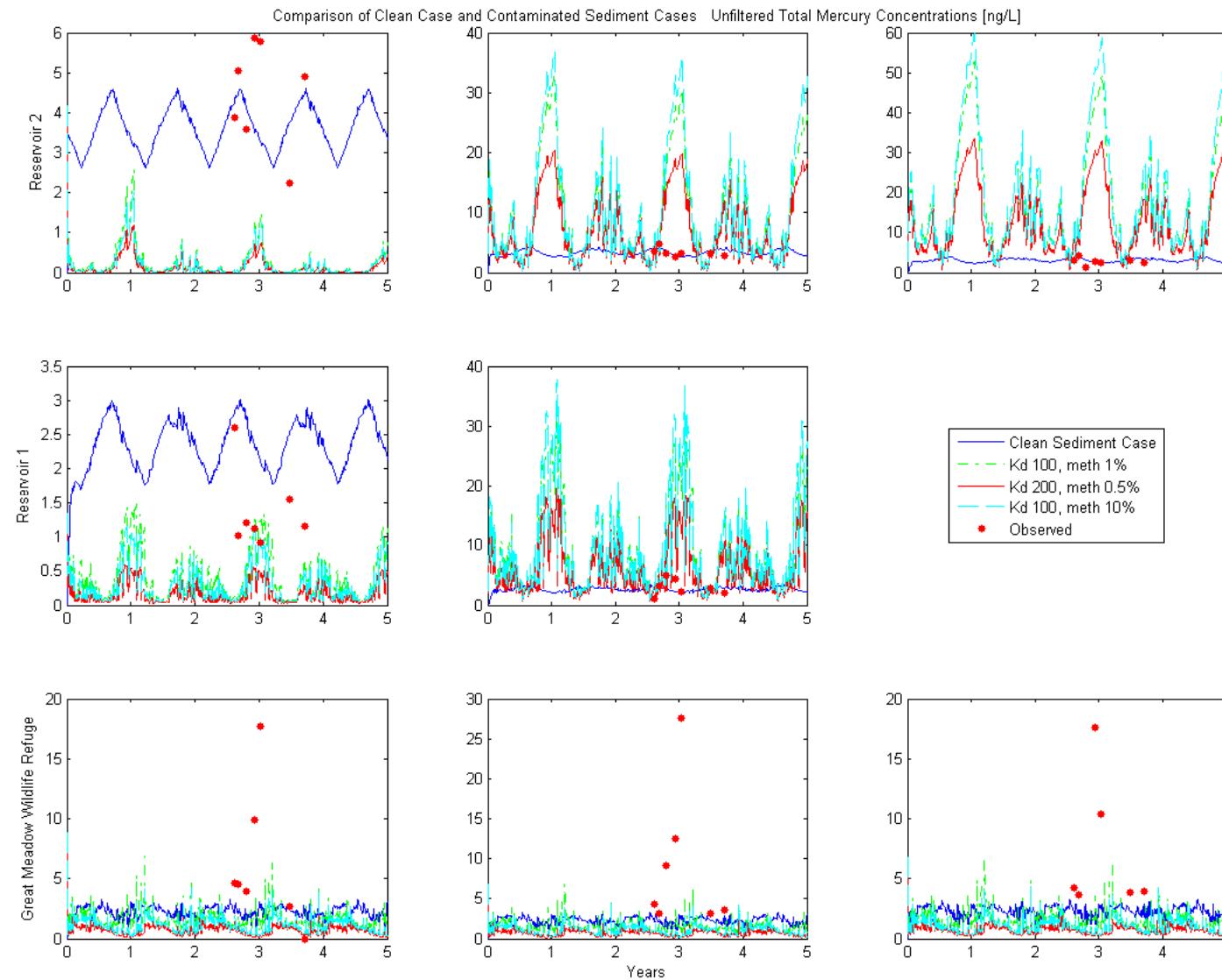
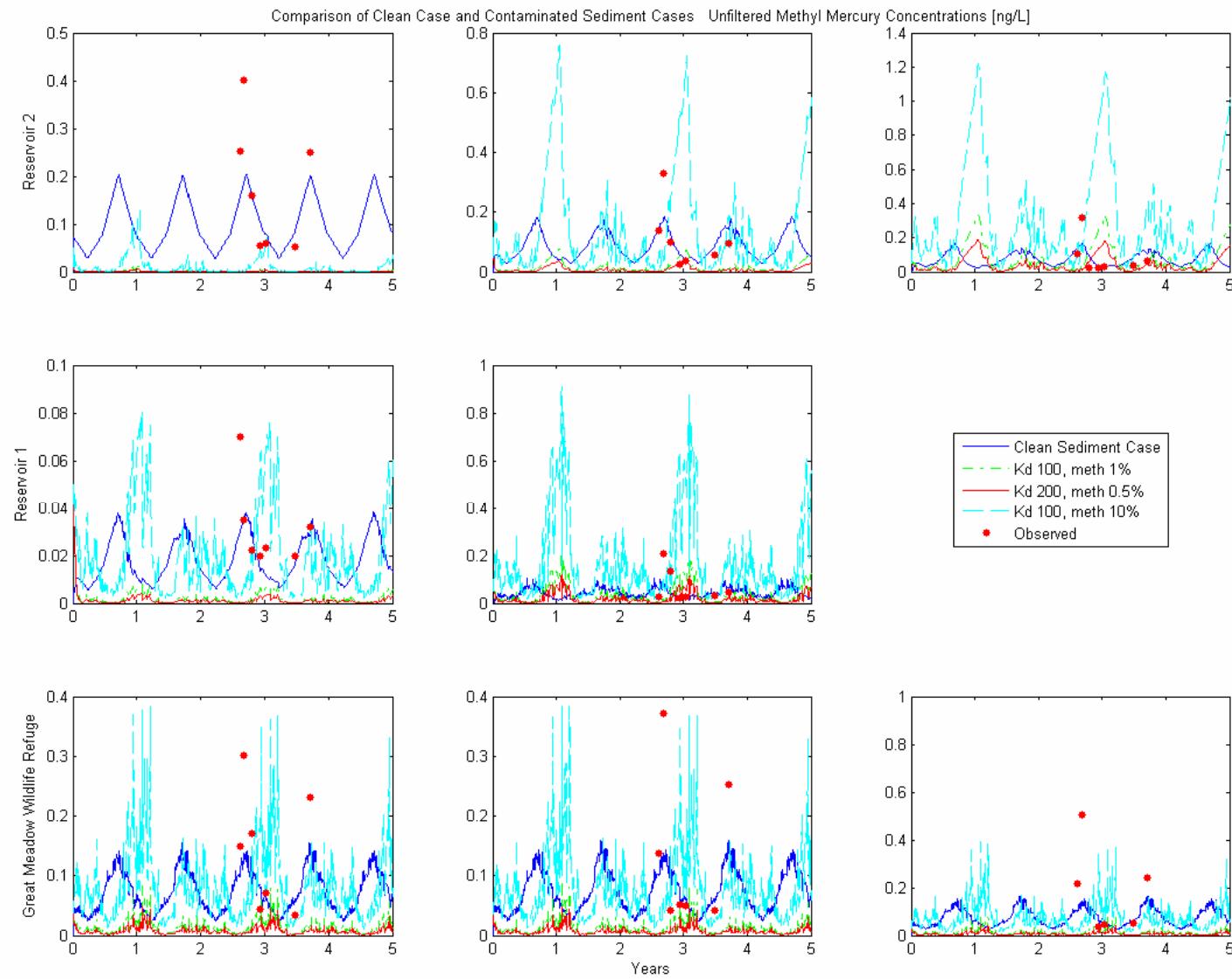


Figure 13. Scenario 2: Comparison of Clean Case (Case 1) and Contaminated Sediment Cases (Case 2A, 2B, 2C). Unfiltered Methyl Mercury Concentration [ng/L]



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Figure 14. Scenario 2: Comparison of Clean Case (Case 1) and Contaminated Sediment Cases (Case 2A, 2B, 2C). Filtered Total Mercury Concentration [ng/L]

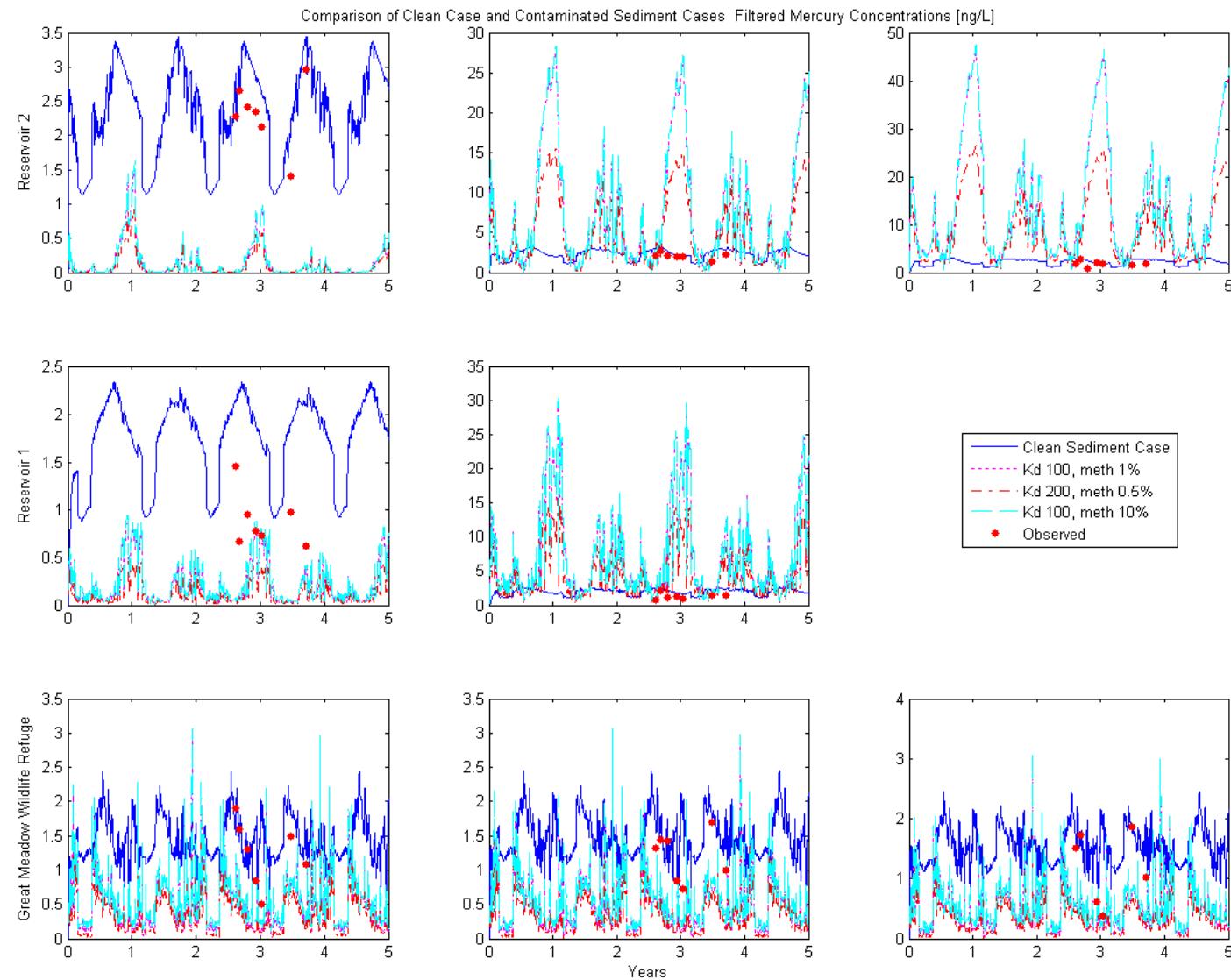


Figure 15. Scenario 2: Comparison of Clean Case (Case 1) and Contaminated Sediment Cases (Case 2A, 2B, 2C). Filtered Methyl Mercury Concentration [ng/L]

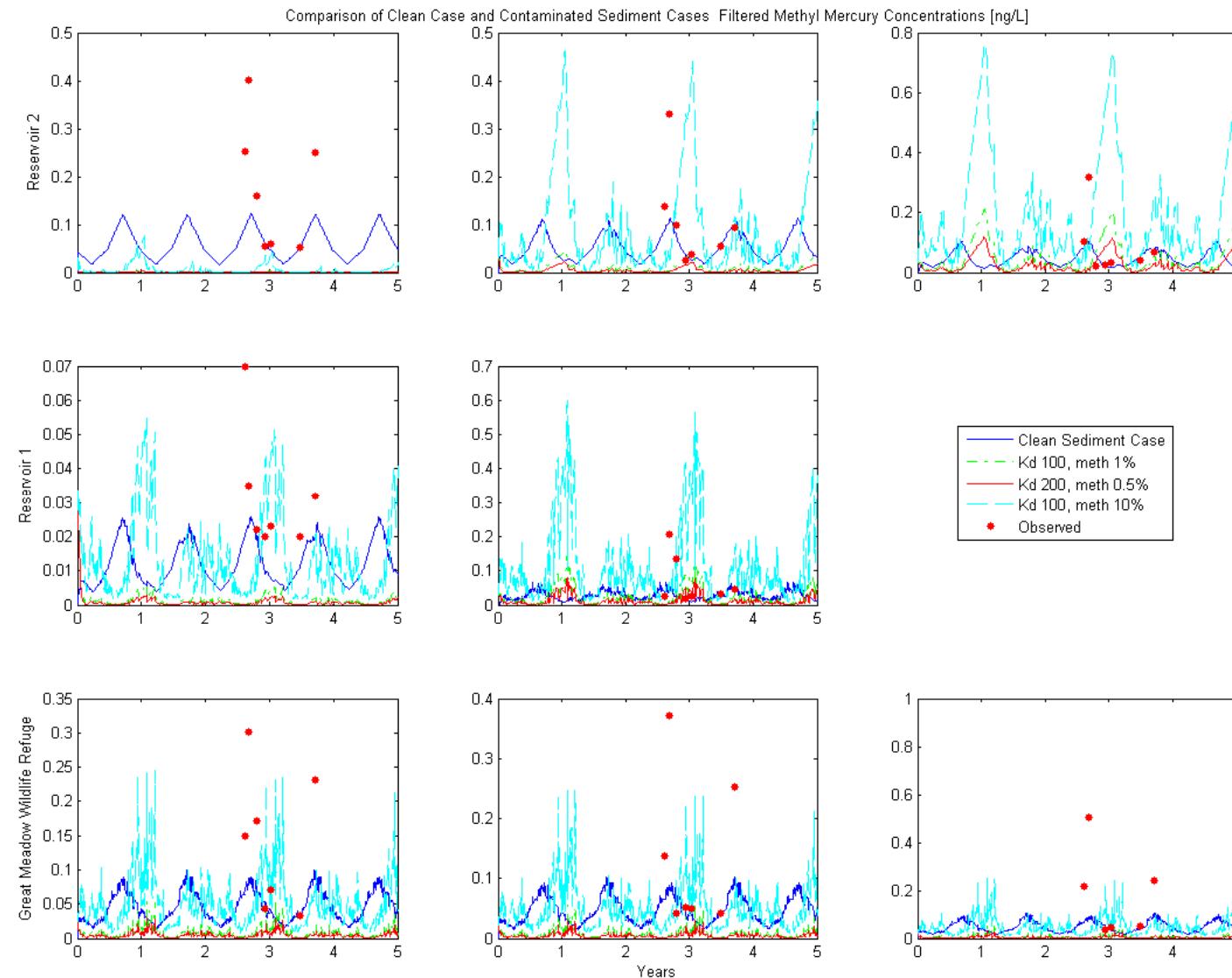


Figure 16. Scenario 2: Clean Case (Case 1) and Addition of Clean Case (Case 1) and the Contaminated Sediment Cases (Case 2A, 2B, 2C). Unfiltered Total Mercury Concentration [ng/L]

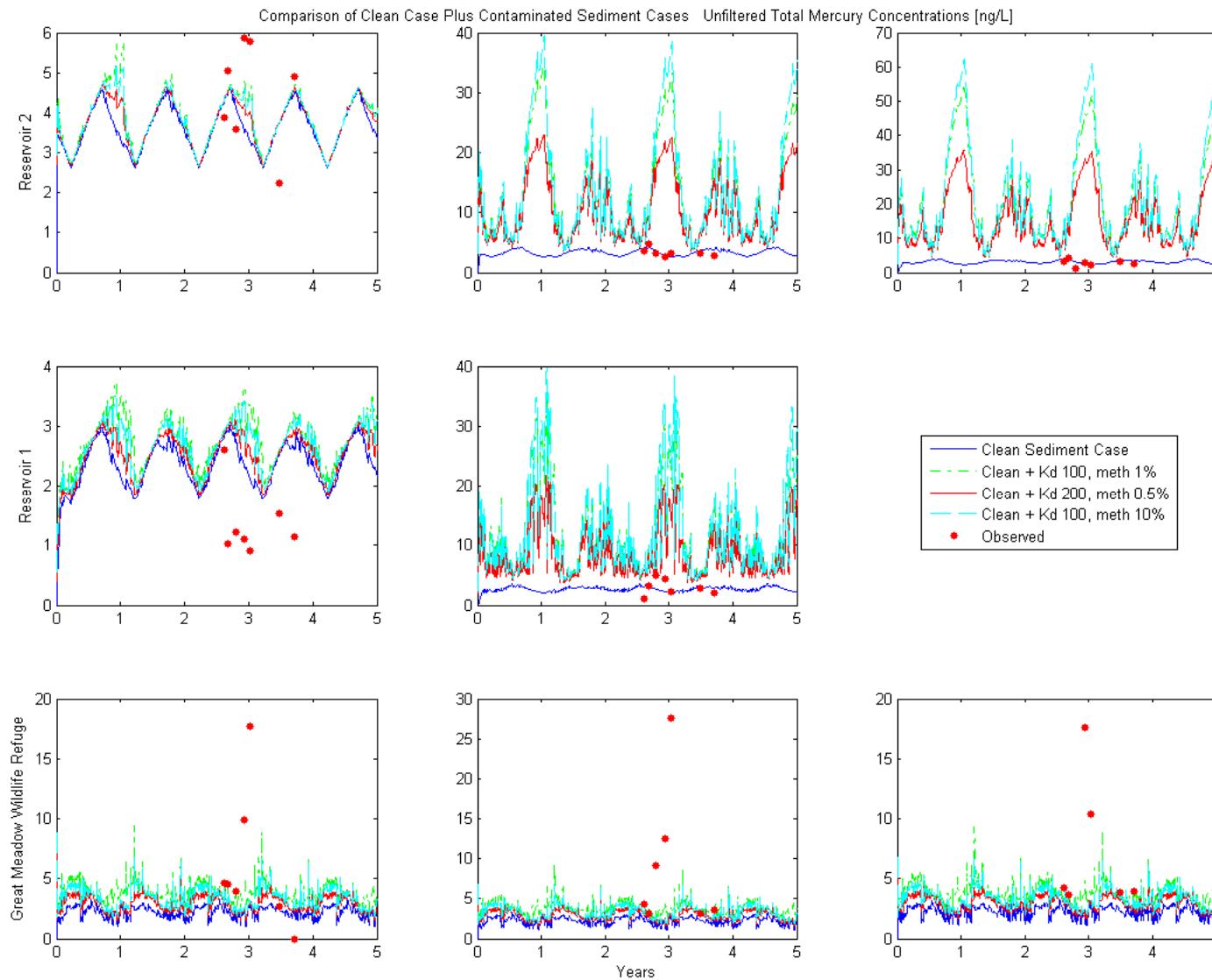


Figure 17. Scenario 2: Clean Case (Case 1) and Addition of Clean Case (Case 1) and the Contaminated Sediment Cases (Case 2A, 2B, 2C). Unfiltered Methyl Mercury Concentration [ng/L]

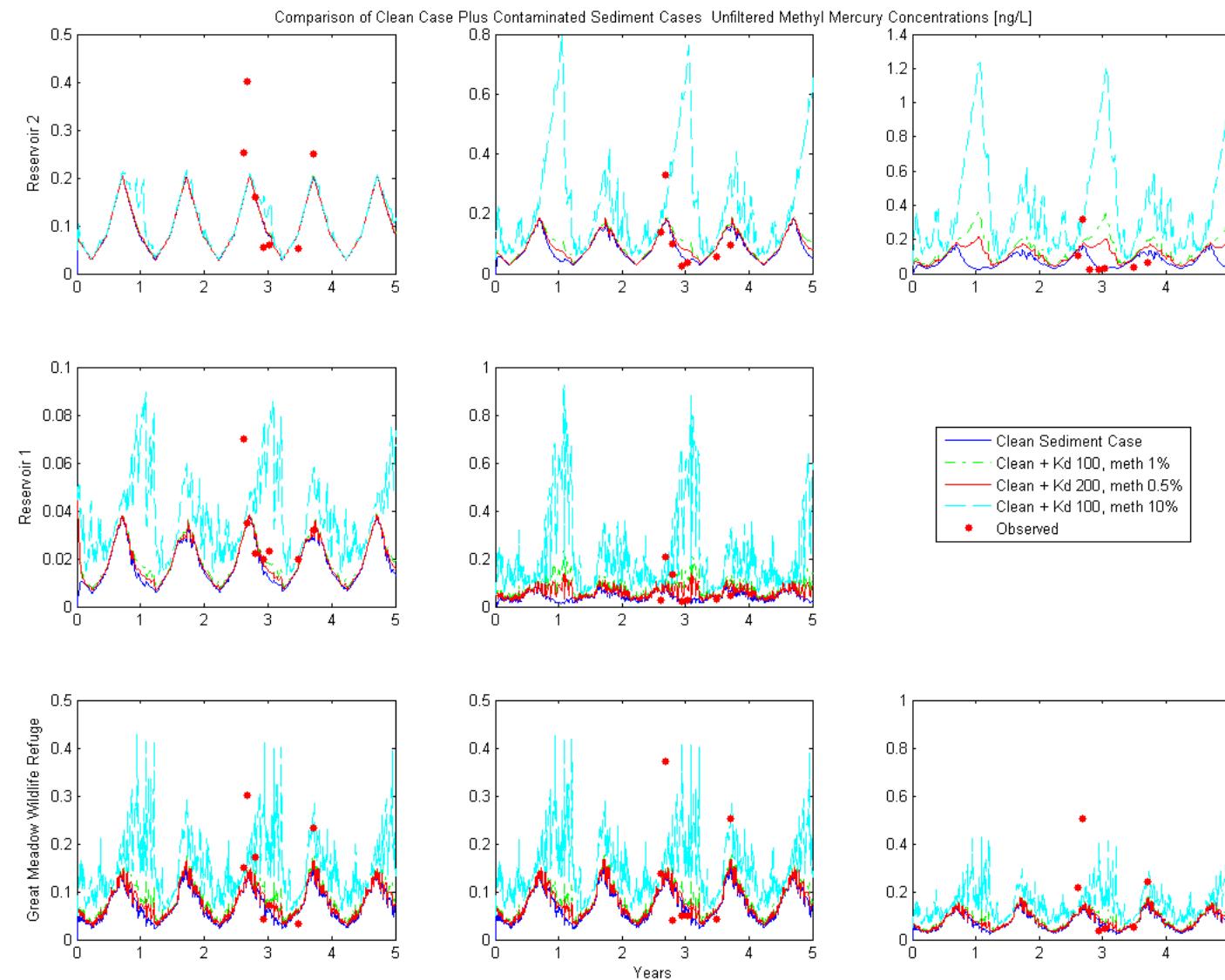


Figure 18. Scenario 2: Clean Case (Case 1) and Addition of Clean Case (Case 1) and the Contaminated Sediment Cases (Case 2A, 2B, 2C). Filtered Total Mercury Concentration [ng/L]

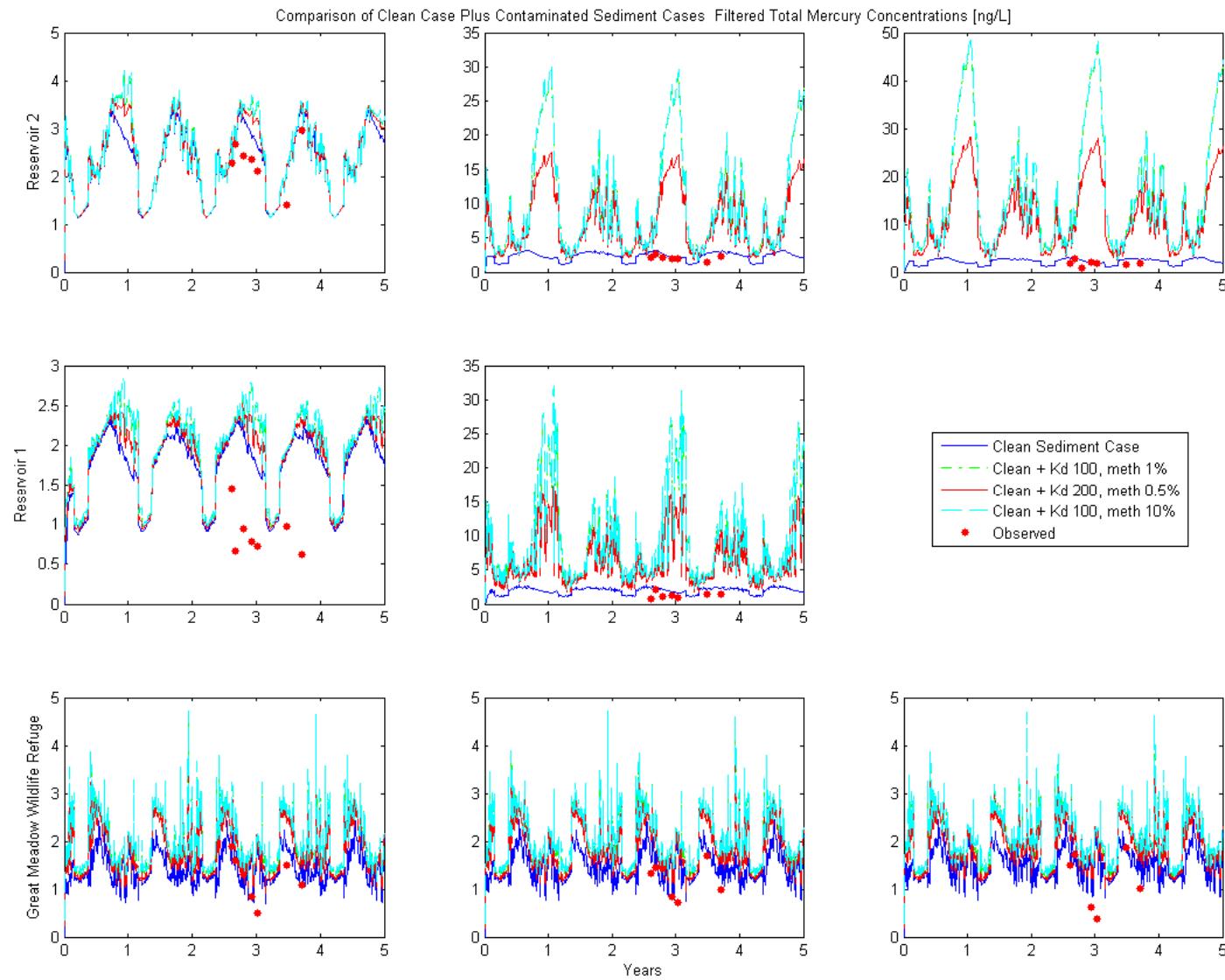


Figure 19. Scenario 2: Clean Case (Case 1) and Addition of Clean Case (Case 1) and the Contaminated Sediment Cases (Case 2A, 2B, 2C). Filtered Methyl Mercury Concentration [ng/L]

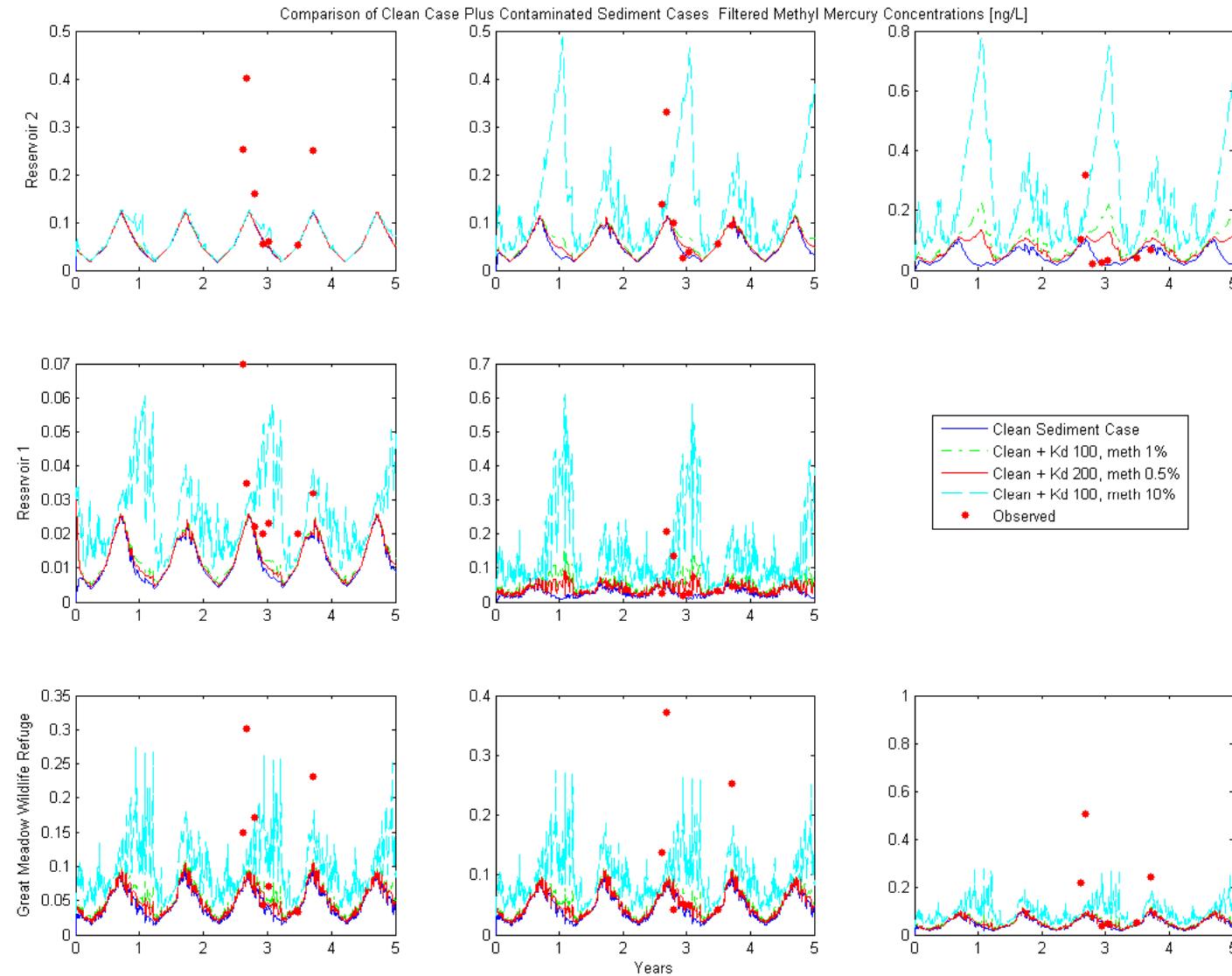


Figure 20. Scenario 3: Doubled Methylation Rates Sensitivity Investigation. Clean Case (Case 3) and Addition of Clean Case (Case 3) and the Contaminated Sediment Cases (Case 3A, 3B, 3C). Unfiltered Total Mercury Concentration [ng/L]

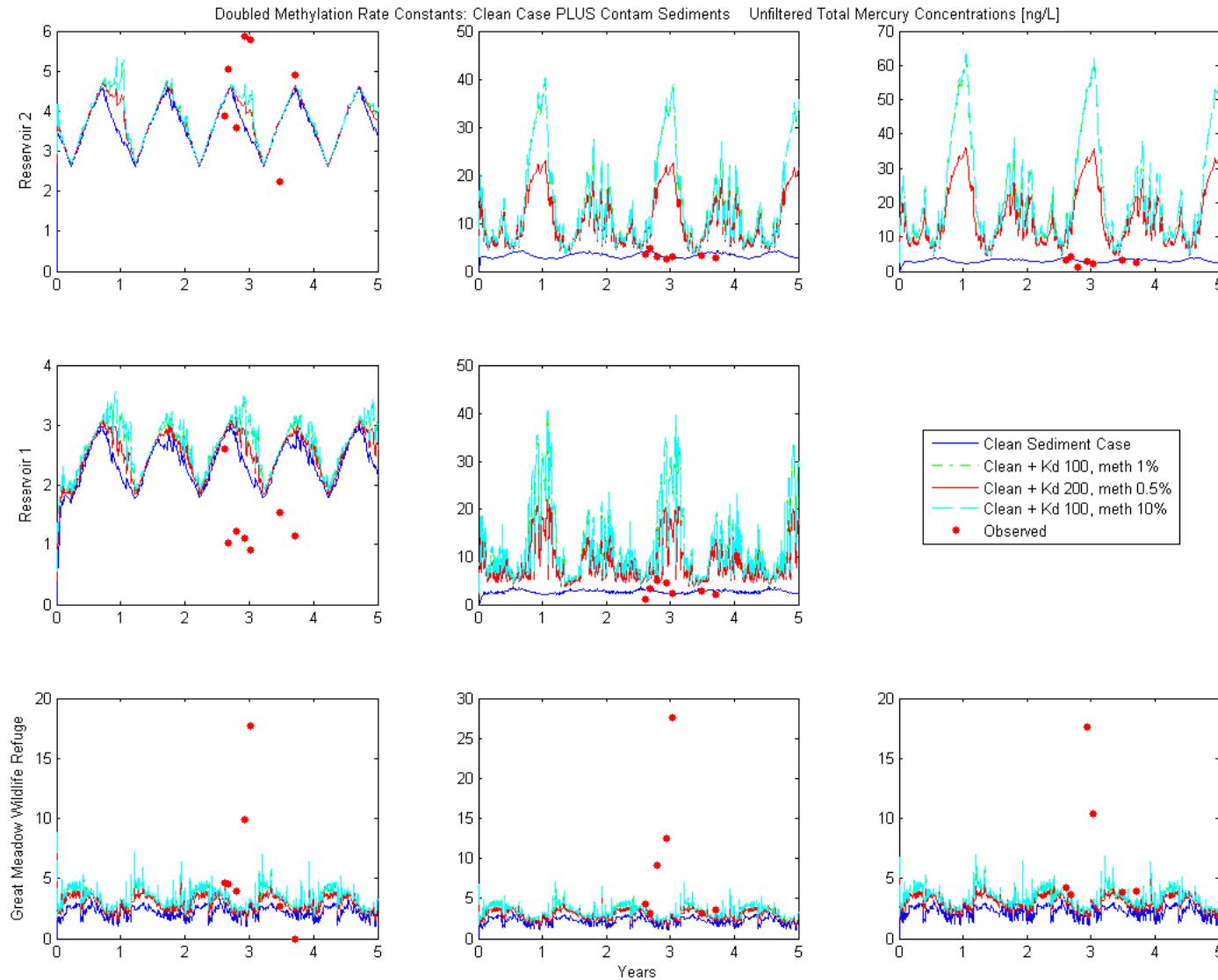


Figure 21. Scenario 3: Doubled Methylation Rates Sensitivity Investigation. Clean Case (Case 3) and Addition of Clean Case (Case 3) and the Contaminated Sediment Cases (Case 3A, 3B, 3C). Unfiltered Methyl Mercury Concentration [ng/L]

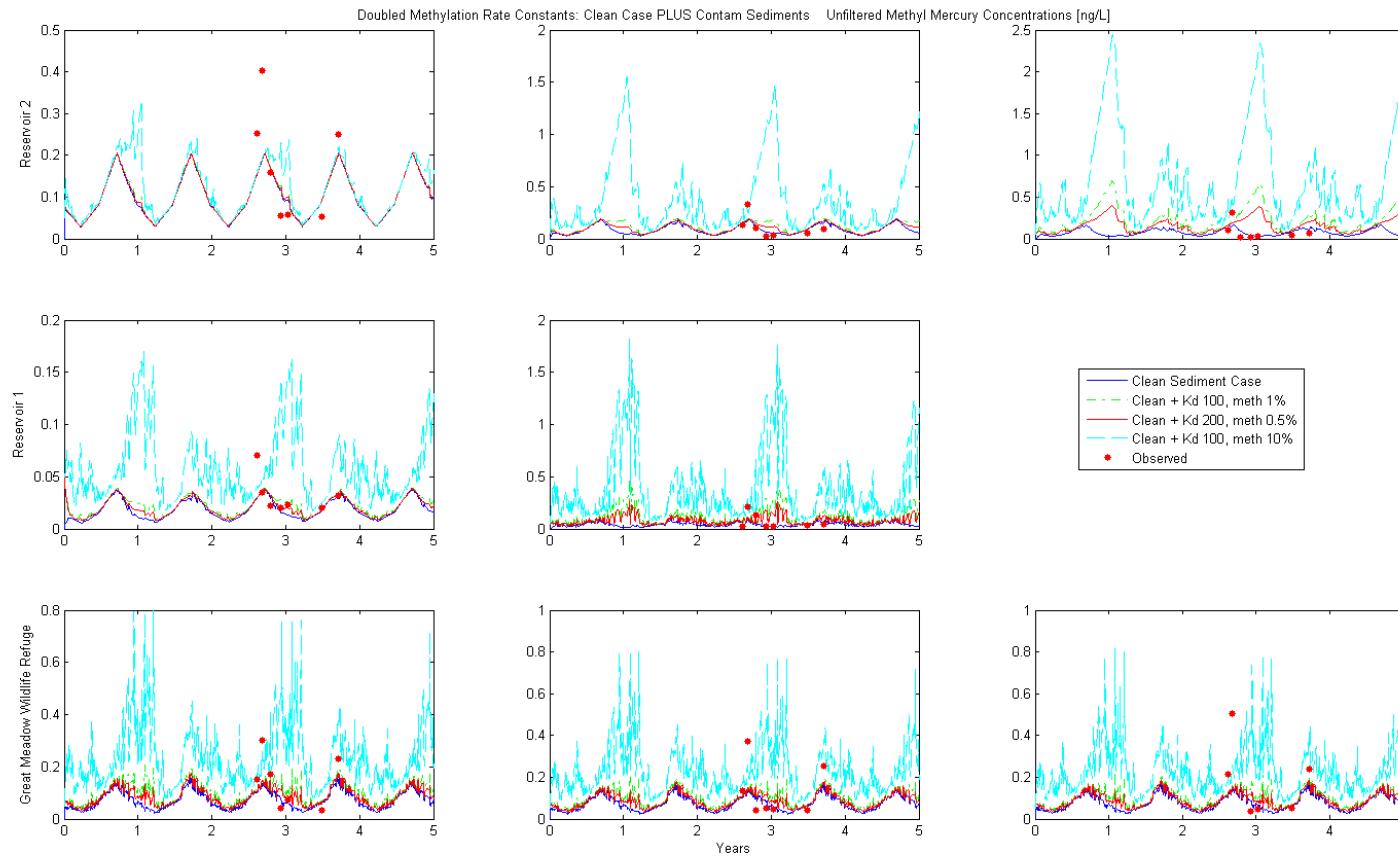


Figure 22. Scenario 3: Doubled Methylation Rates Sensitivity Investigation. Clean Case (Case 3) and Addition of Clean Case (Case 3) and the Contaminated Sediment Cases (Case 3A, 3B, 3C). Filtered Total Mercury Concentration [ng/L]

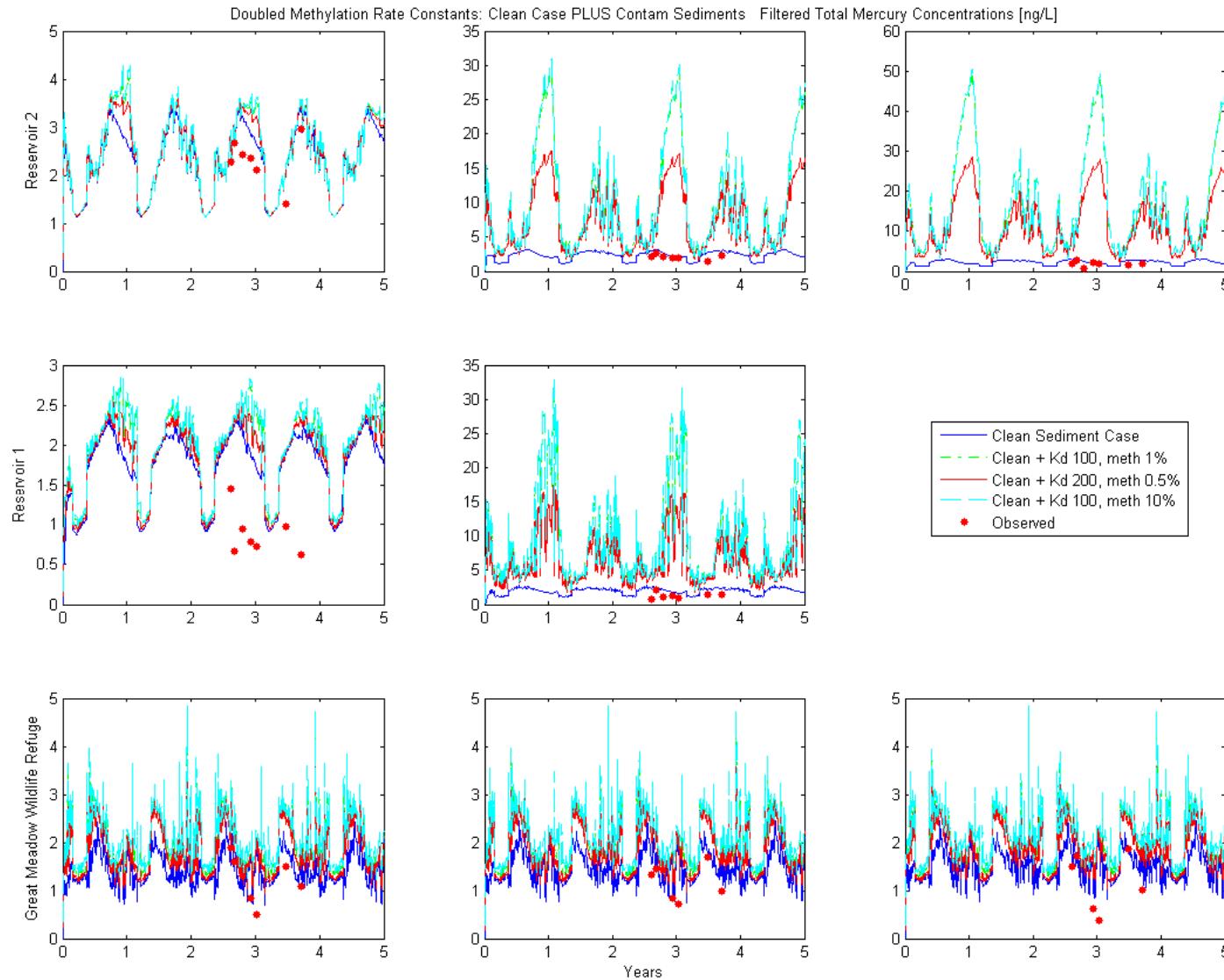


Figure 23. Scenario 3: Doubled Methylation Rates Sensitivity Investigation. Clean Case (Case 3) and Addition of Clean Case (Case 3) and the Contaminated Sediment Cases (Case 3A, 3B, 3C). Filtered Methyl Mercury Concentration [ng/L]

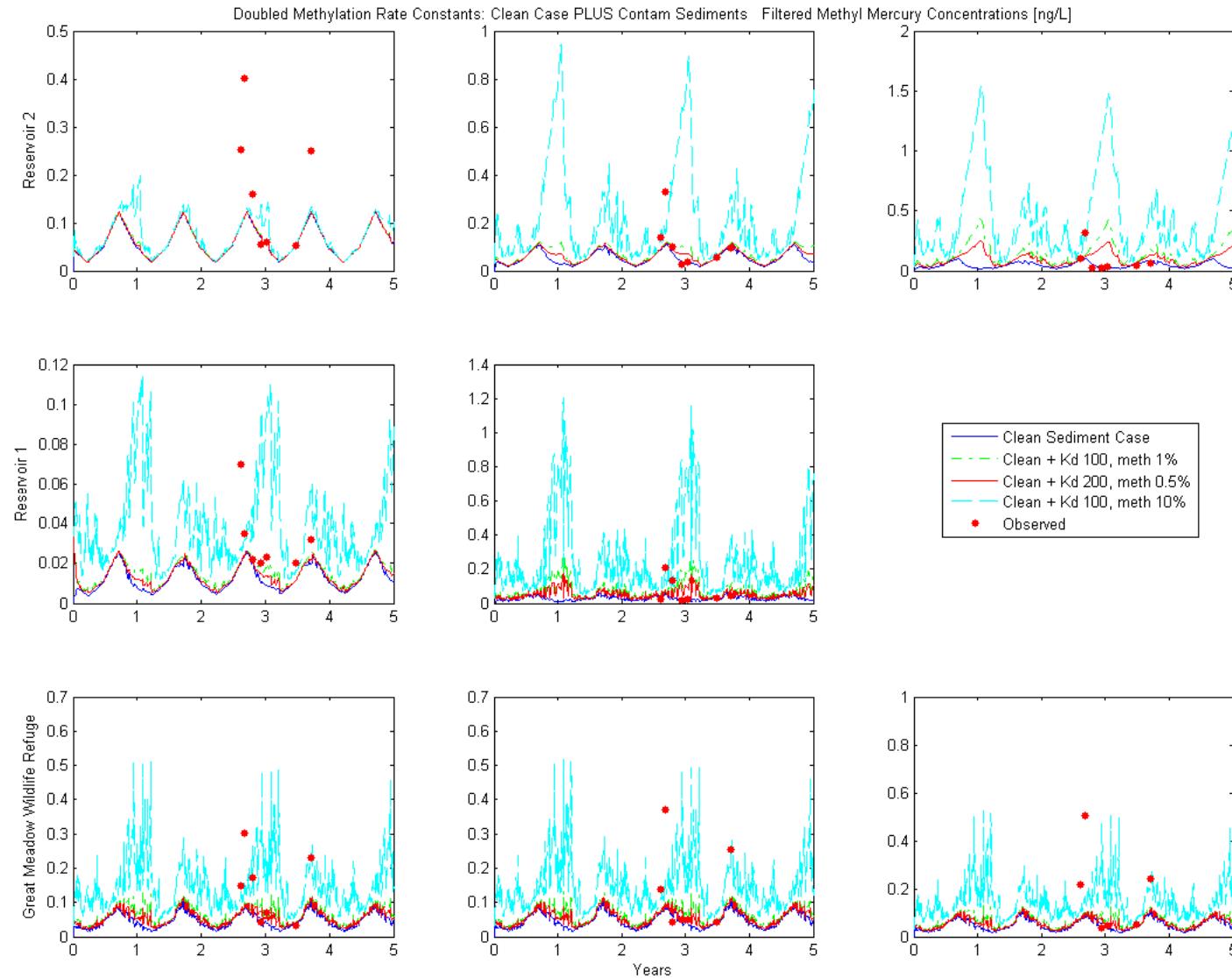


Figure 24. Final Model, Predicted Unfiltered Total Mercury Concentrations with Observed Values.

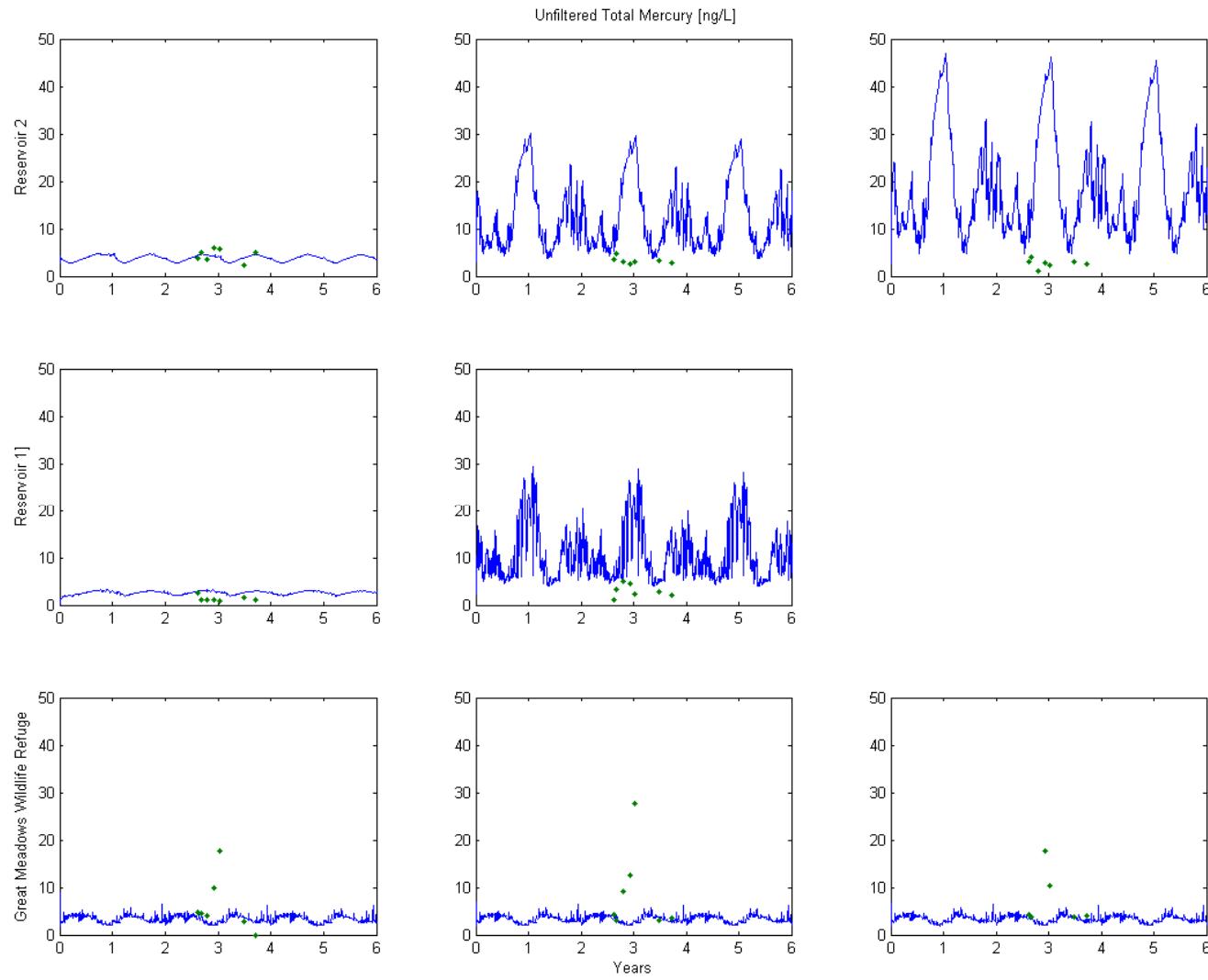


Figure 25. Final Model, Predicted Unfiltered Methyl Mercury Concentrations with Observed Values.

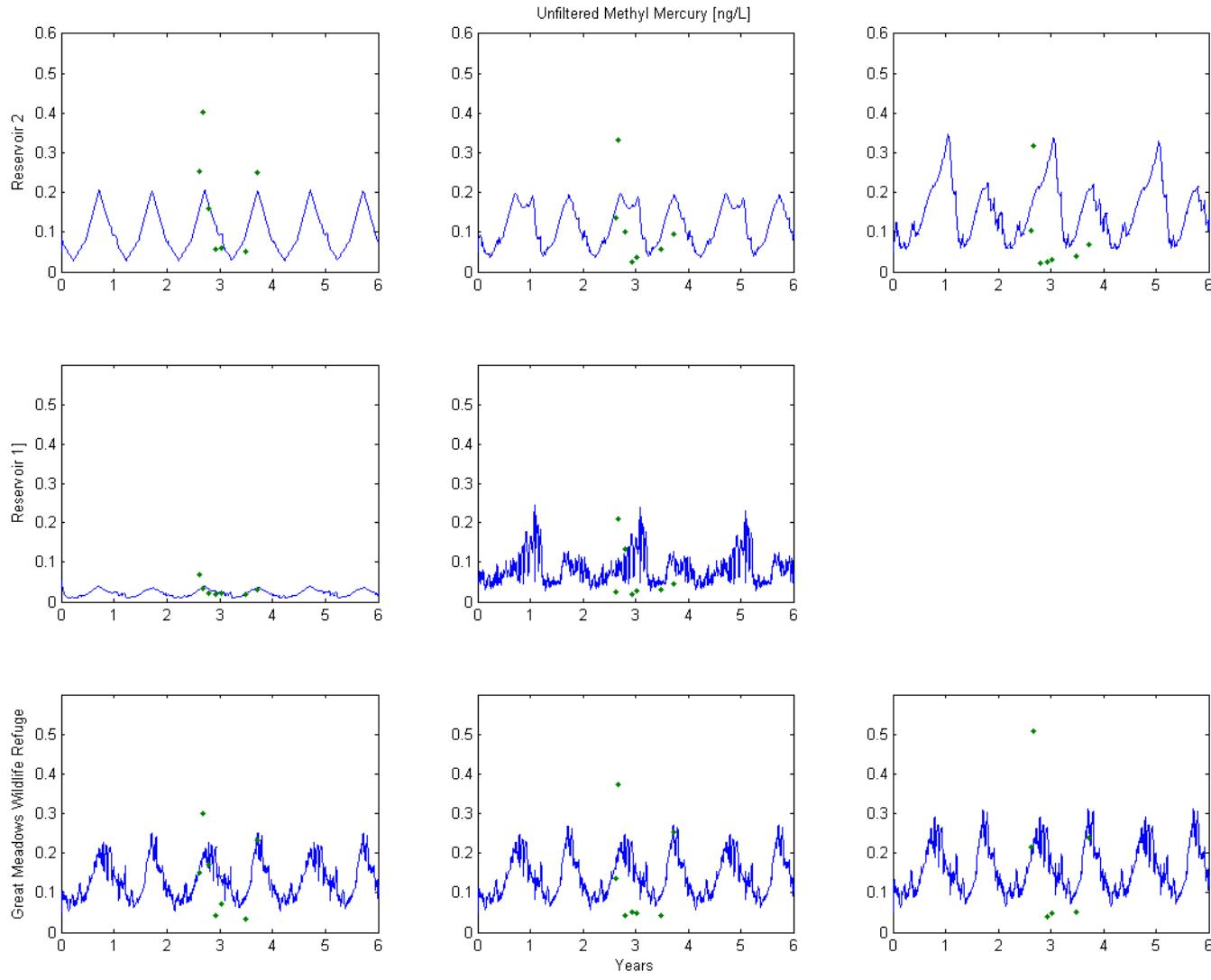


Figure 26. Final Model, Predicted Filtered Total Mercury Concentrations with Observed Values.

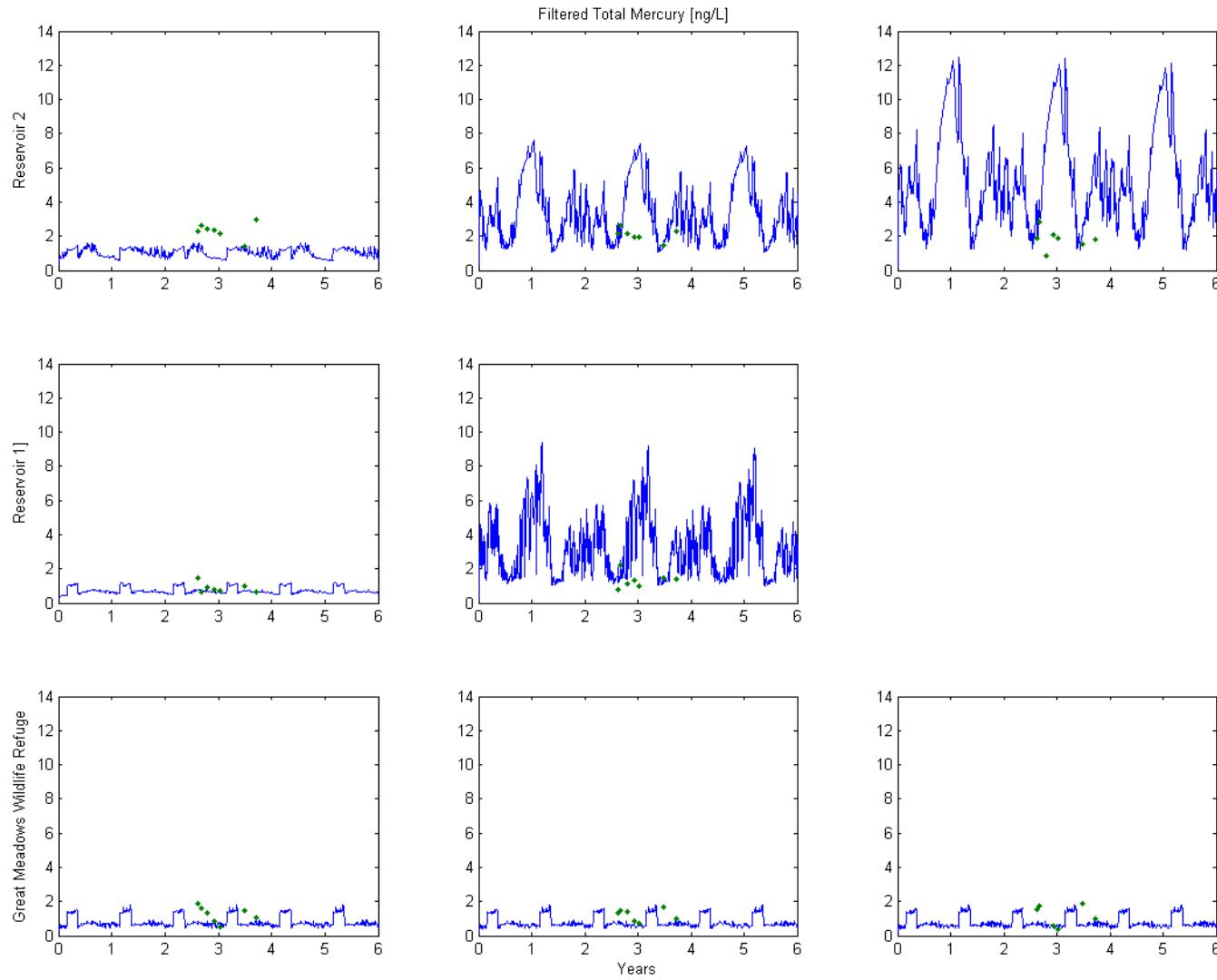


Figure 27. Final Model, Predicted Filtered Methyl Mercury Concentrations with Observed Values.

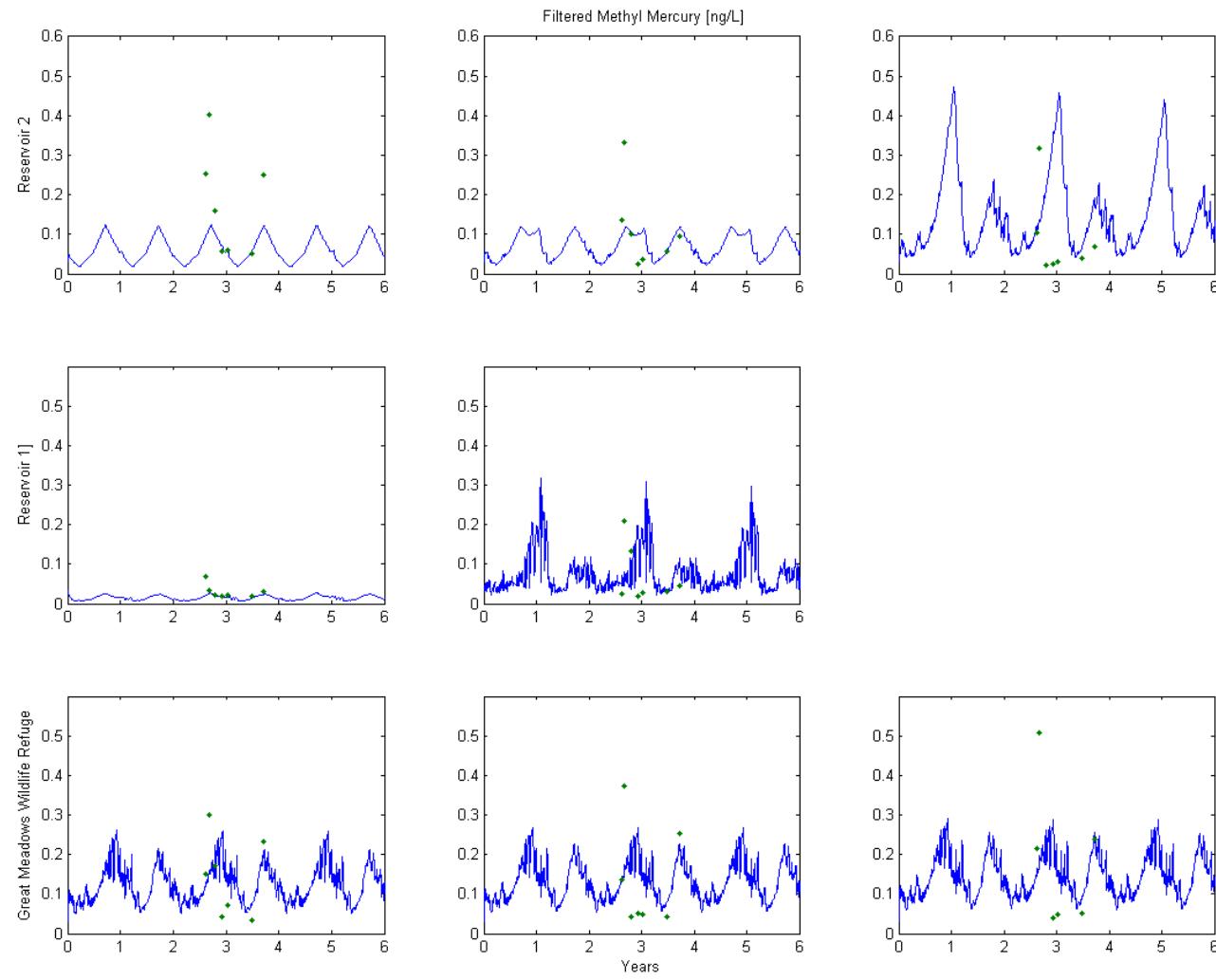


Figure 28. Comparison of Predicted versus Observed (Unfiltered Total Hg) for each Sampling Location for Final Model Design and Output: Annual Means and Standard Deviations

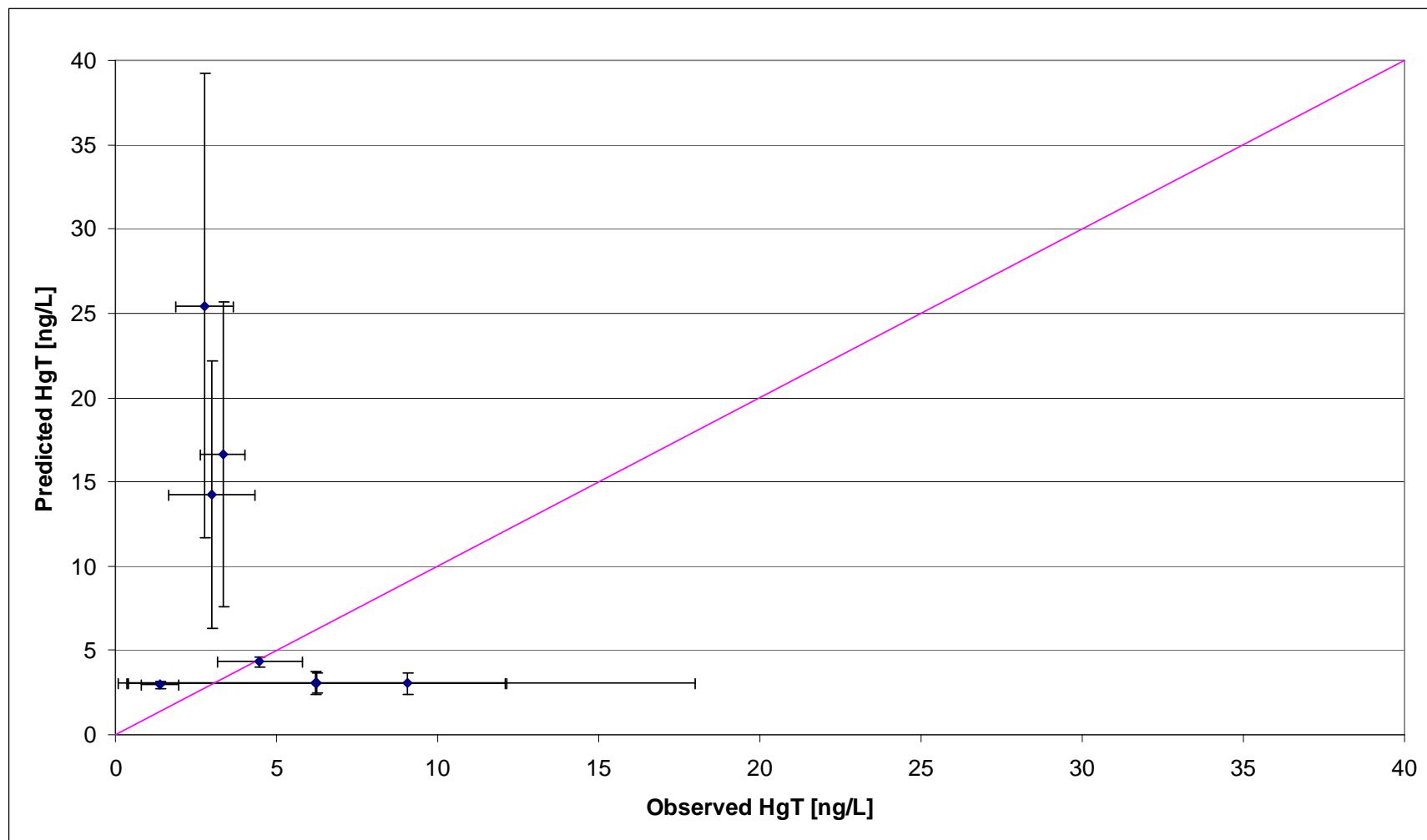


Figure 29. Comparison of Predicted versus Observed (Unfiltered MeHg) for each Sampling Location for Final Model Design and Output: Annual Means and Standard Deviations

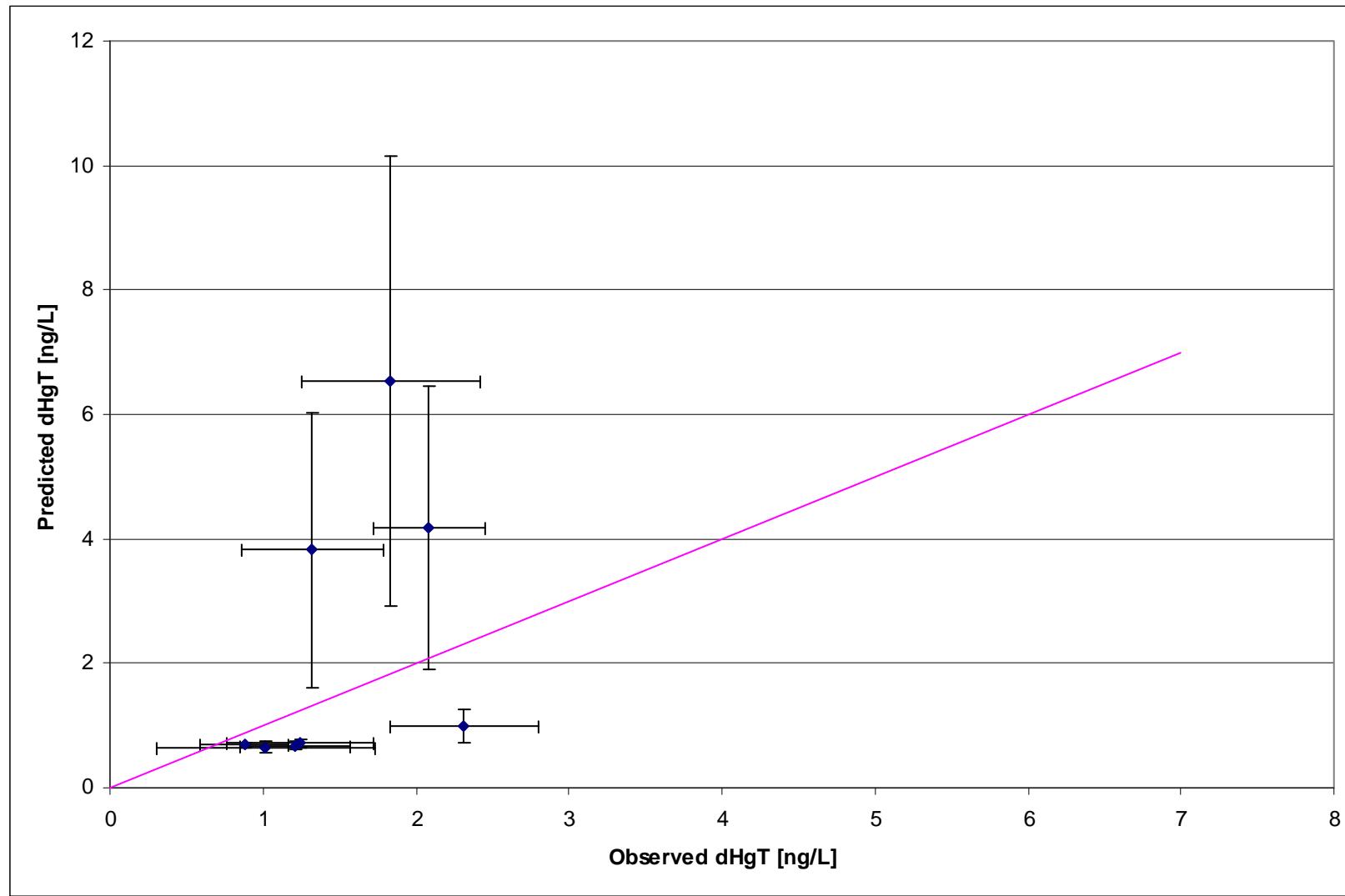


Figure 30. Comparison of Predicted versus Observed (Filtered Total Hg) for each Sampling Location for Final Model Design and Output: Annual Means and Standard Deviations

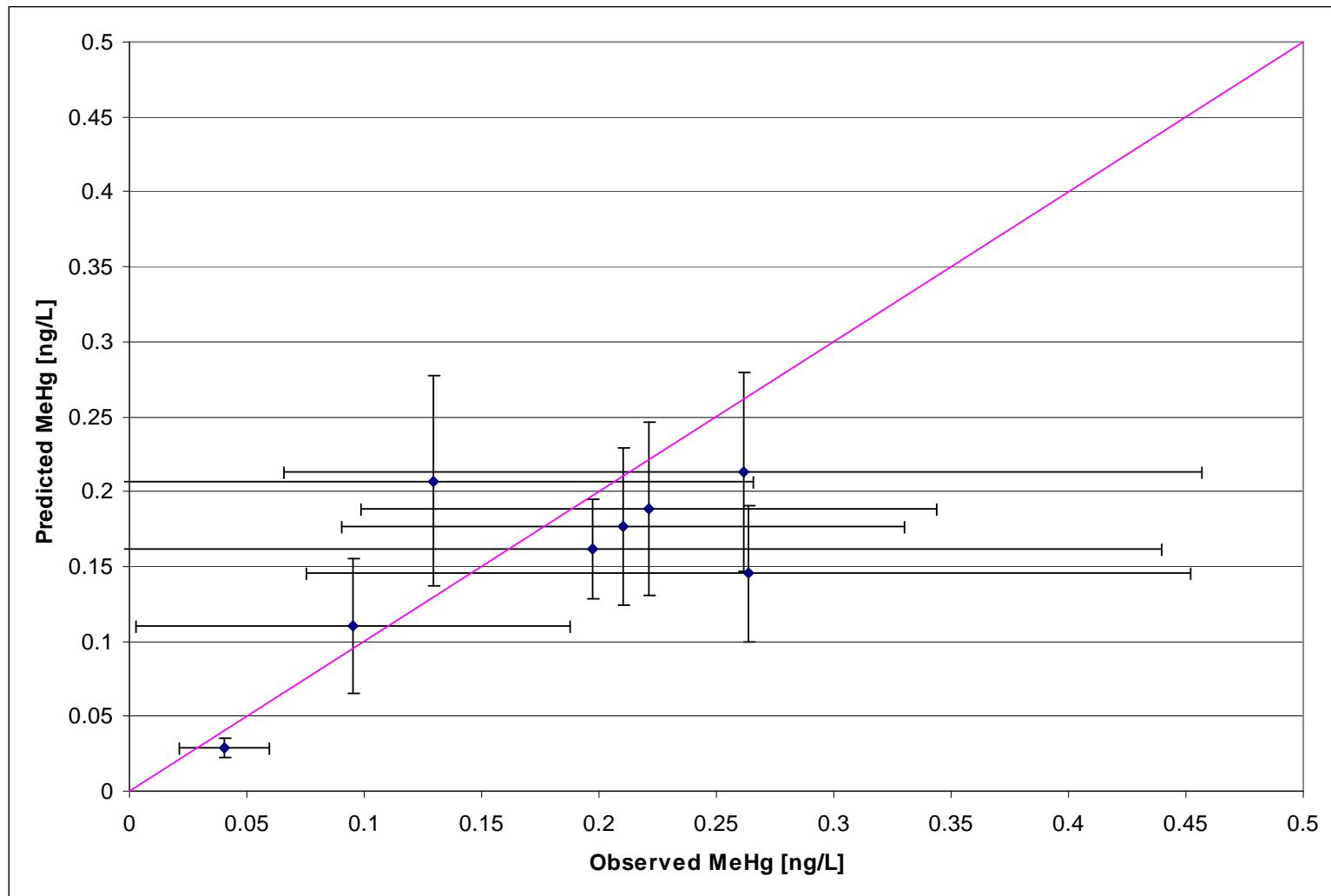


Figure 31. Comparison of Predicted versus Observed (Filtered MeHg) for each Sampling Location for Final Model Design and Output: Annual Means and Standard Deviations

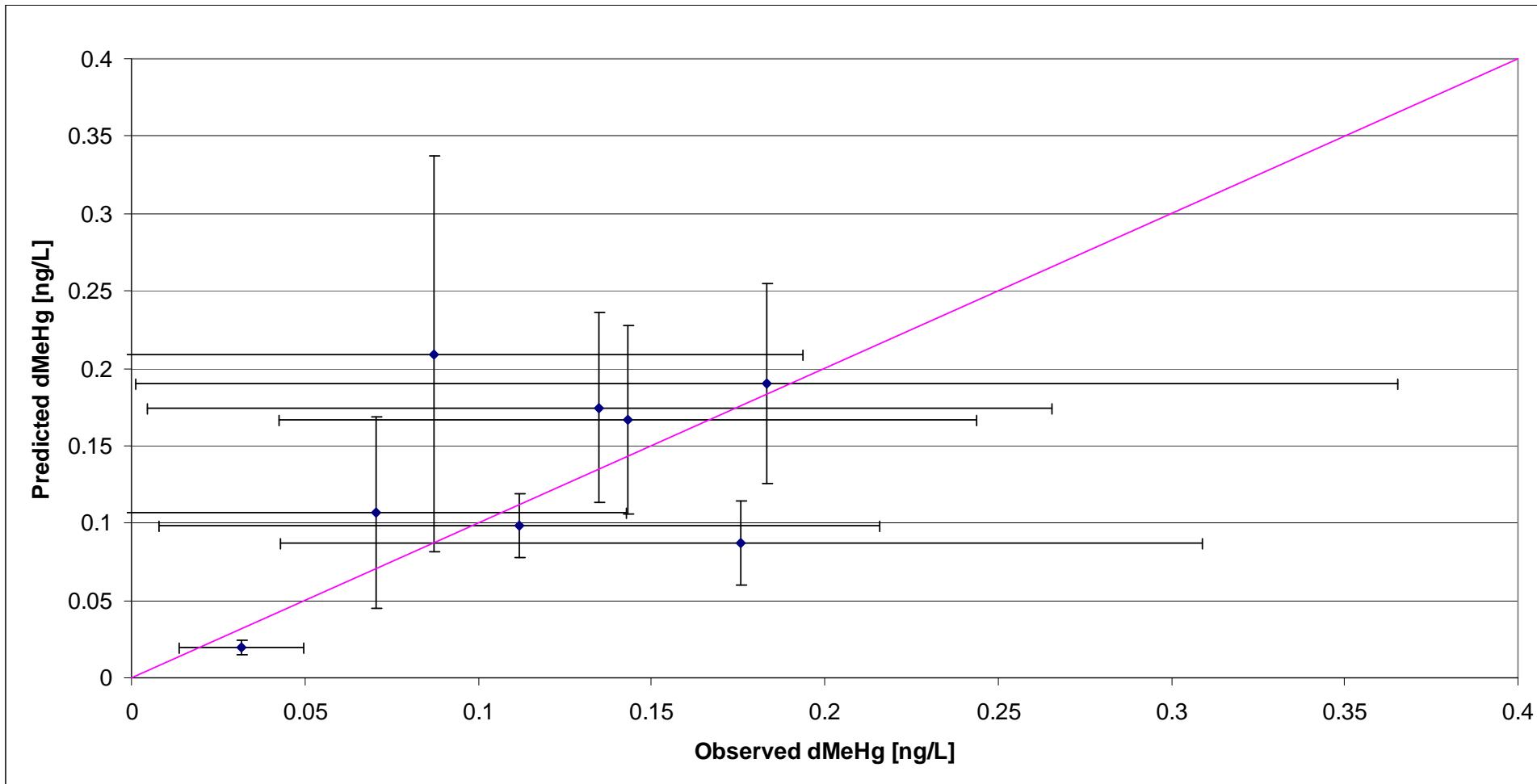


Figure 32. Final Model Future Predictions for 30 yrs for Filtered (dissolved) MeHg in surface water for Sudbury River Reaches 3 –

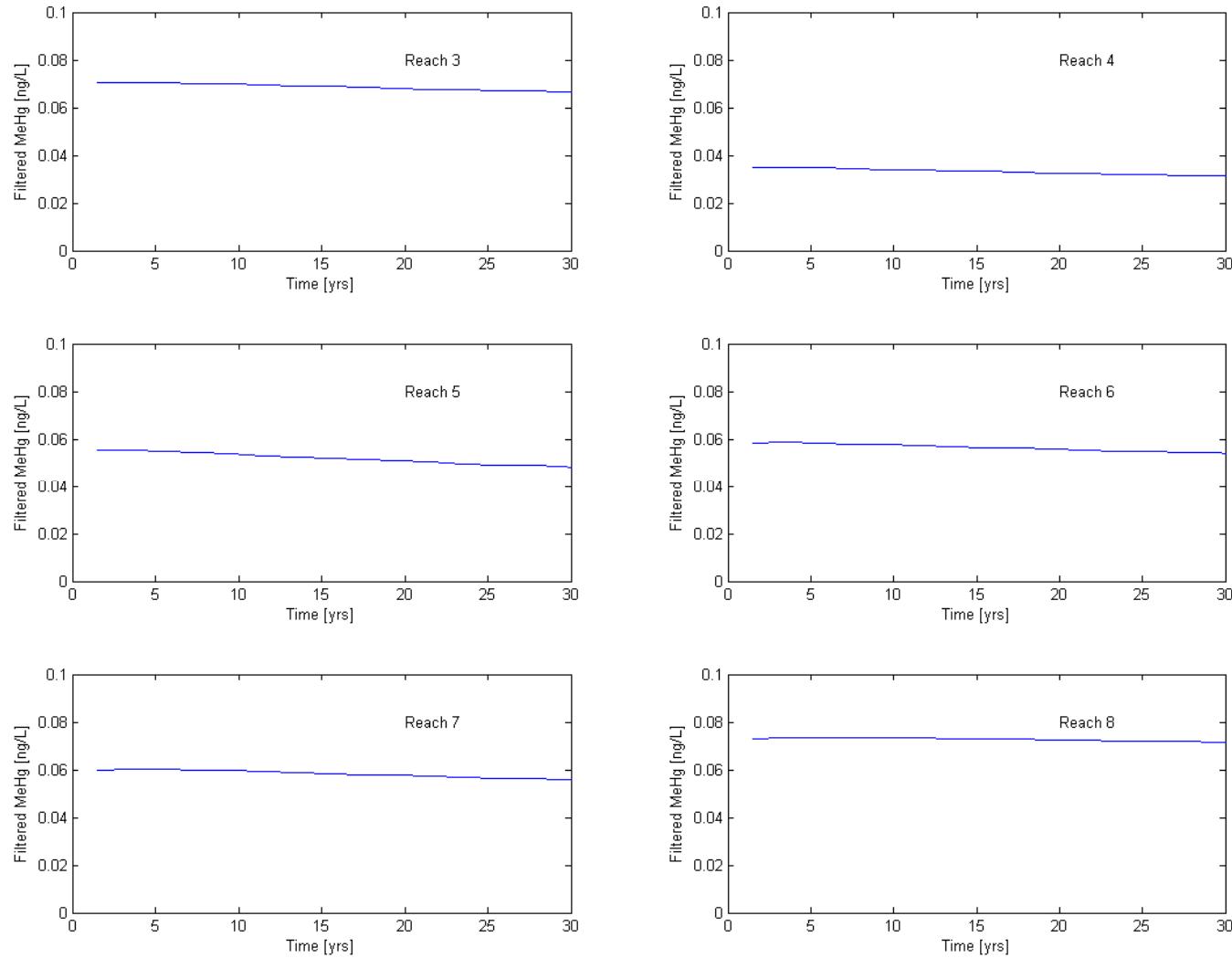
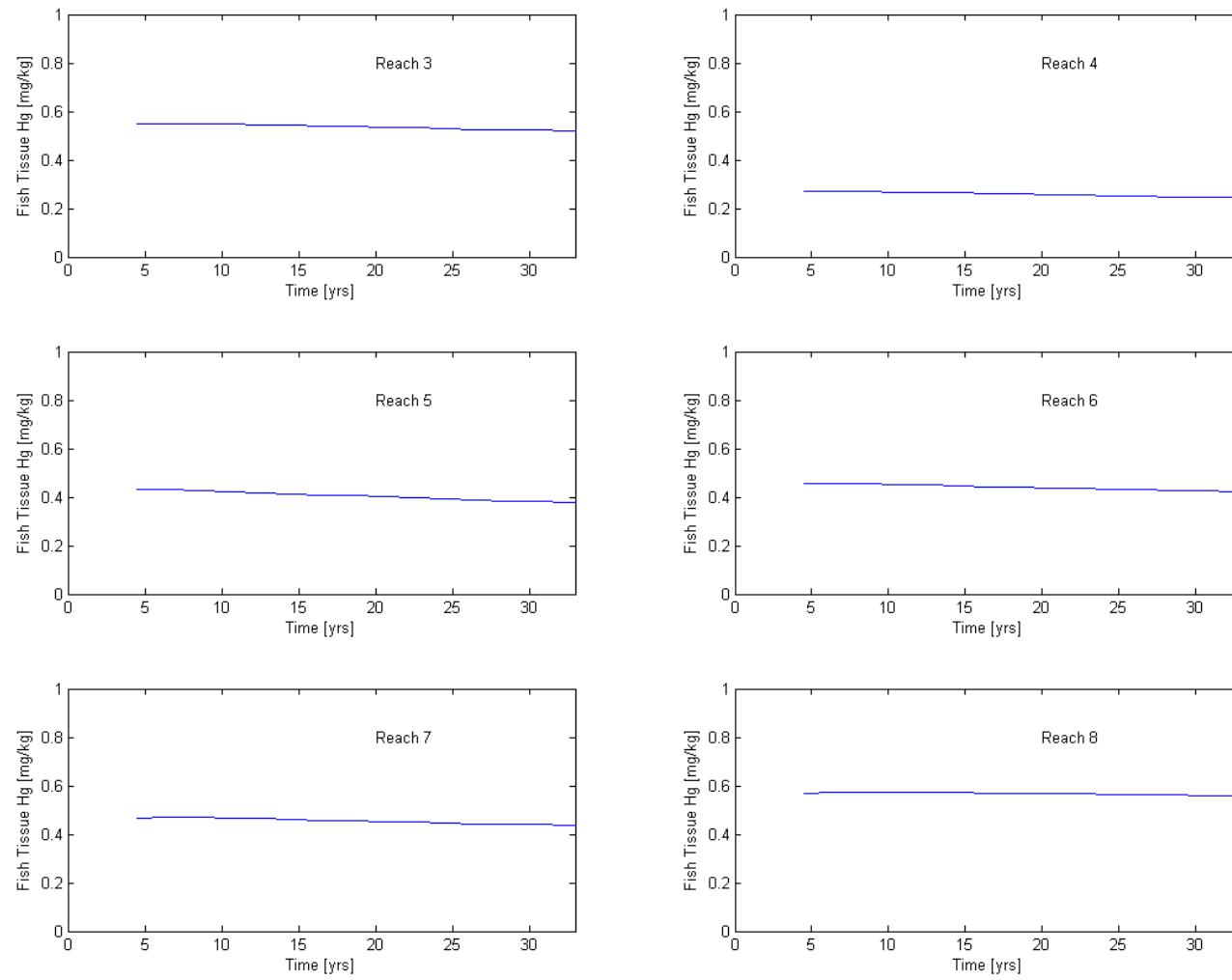


Figure 33. Final Model Future Predictions for 30 yrs for Filtered (dissolved) MeHg in surface water for Sudbury River Reaches 3 – 8



APPENDIX A
Supplementary Tables

Table A-1. Model Segmentation and Dimensions

Reach	Segment	Description	Volume [m³]	Length [m]	Width [m]	Depth [m]
3	1	Upstream_Res_2	10452	402	20	1.3
3	2	Reservoir_2_first_leg	27104	220	77	1.6
3	3	Res2_secleg	134000	670	100	2
3	4	Res2mid	227550	740	123	2.5
3	5	Res2end	644160	1220	240	2.2
4	6	Res1from3	637560	1610	180	2.2
4	7	Reservoir1	169769.6	742	104	2.2
5	8	SudburyRiverafterRes1	16400	820	20	1
5	9	SudburyRiverReach9	17640	882	20	1
5	10	SudburyRiverReach10	9408	784	20	0.6
5	11	SudburyRiverReach11	7560	630	20	0.6
5	12	SudburyRiverReach12	7560	630	20	0.6
5	13	SudburyRiverReach13	9468	789	20	0.6
5	14	SudburyRiverPond	34125	604	57.95	0.975
6	15	start_of_Saxonville_Pond	66960	730.67	98.54	0.93
6	16	midSaxonvillePond	66960	730.67	98.54	0.93
6	17	endSaxonvillePond	66960	730.67	98.54	0.93
7	18	SaxonvilleDam1	28740	958.00	20.00	1.5
7	19	SaxonvilleDam2	21032.6	1021.00	20.00	1.03
7	20	SaxonvilleDam3	18837	897.00	20.00	1.05
7	21	SaxonvilleDam4	23435	1075.00	20.00	1.09
7	22	HeardPondSwampMarsh	825000	2423.00	309.53	1.1
7	23	MarshReach24	152400	1814.29	70.00	1.2
8	24	UpofGMNWR	23568	982.00	20.00	1.2
8	25	GMNWR1	28152	1173.00	20.00	1.2
8	26	GMNWR2	24240	1010.00	20.00	1.2
8	27	GMNWR3	31824	1326.00	20.00	1.2
8	28	GMNWR4	31200	1300.00	20.00	1.2
8	29	GMNWR5	25104	1046.00	20.00	1.2
8	30	GMNWR6	25296	1054.00	20.00	1.2
8	31	GMNWR7	29736	1239.00	20.00	1.2
8	32	GMNWR8	26520	1105.00	20.00	1.2
8	33	GMNWR9	35256	1469.00	20.00	1.2
	34	SedUpstream_Res_2	160.8	402	20	0.02
	35	SedReservoir_2_first_leg	338.8	220	77	0.02
	36	SedRes2_secleg	1340	670	100	0.02
	37	SedRes2mid	1820.4	740	123	0.02
	38	SedRes2end	5856	1220	240	0.02
	39	SedRes1from3	5796	1610	180	0.02
	40	SedReservoir1	1543.36	742	104	0.02
	41	SedSudburyRiverafterRes1	328	820	20	0.02
	42	SedSudburyRiverReach9	352.8	882	20	0.02
	43	SedSudburyRiverReach10	313.6	784	20	0.02
	44	SedSudburyRiverReach11	252	630	20	0.02
	45	SedSudburyRiverReach12	252	630	20	0.02
	46	SedSudburyRiverReach13	315.6	789	20	0.02
	47	SedSudburyRiverPond	700	604	57.95	0.02

48	Sedstart_of_Saxonville_Pond	1440	730.67	98.54	0.02
49	SedmidSaxonvillePond	1440	730.67	98.54	0.02
50	SedendSaxonvillePond	1440	730.67	98.54	0.02
51	SedSaxonvilleDam1	383.2	958.00	20.00	0.02
52	SedSaxonvilleDam2	408.4	1021.00	20.00	0.02
53	SedSaxonvilleDam3	358.8	897.00	20.00	0.02
54	SedSaxonvilleDam4	430	1075.00	20.00	0.02
55	SedHeardPondSwampMarsh	15000	2423.00	309.53	0.02
56	SedMarshReach24	2540	1814.29	70.00	0.02
57	SedUpofGMNWR	392.8	982.00	20.00	0.02
58	SedGMNWR1	469.2	1173.00	20.00	0.02
59	SedGMNWR2	404	1010.00	20.00	0.02
60	SedGMNWR3	530.4	1326.00	20.00	0.02
61	SedGMNWR4	520	1300.00	20.00	0.02
62	SedGMNWR5	418.4	1046.00	20.00	0.02
63	SedGMNWR6	421.6	1054.00	20.00	0.02
64	SedGMNWR7	495.6	1239.00	20.00	0.02
65	SedGMNWR8	442	1105.00	20.00	0.02
66	SedGMNWR9	587.6	1469.00	20.00	0.02
67	SubSedUpstream_Res_2	402	402	20	0.05
68	SubSedReservoir_2_first_leg	847	220	77	0.05
69	SubSedRes2_secleg	3350	670	100	0.05
70	SubSedRes2mid	4551	740	123	0.05
71	SubSedRes2end	14640	1220	240	0.05
72	SubSedRes1from3	14490	1610	180	0.05
73	SubSedReservoir1	3858.4	742	104	0.05
74	SubSedSudburyRiverafterRes1	820	820	20	0.05
75	SubSedSudburyRiverReach9	882	882	20	0.05
76	SubSedSudburyRiverReach10	784	784	20	0.05
77	SubSedSudburyRiverReach11	630	630	20	0.05
78	SubSedSudburyRiverReach12	630	630	20	0.05
79	SubSedSudburyRiverReach13	789	789	20	0.05
80	SubSedSudburyRiverPond	1750	604	57.95	0.05
81	SubSedstart_of_Saxonville_Pond	3600	730.67	98.54	0.05
82	SubSedmidSaxonvillePond	3600	730.67	98.54	0.05
83	SubSedendSaxonvillePond	3600	730.67	98.54	0.05
84	SubSedSaxonvilleDam1	958	958.00	20.00	0.05
85	SubSedSaxonvilleDam2	1021	1021.00	20.00	0.05
86	SubSedSaxonvilleDam3	897	897.00	20.00	0.05
87	SubSedSaxonvilleDam4	1075	1075.00	20.00	0.05
88	SubSedHeardPondSwampMarsh	37500	2423.00	309.53	0.05
89	SubSedMarshReach24	6350	1814.29	70.00	0.05
90	SubSedUpofGMNWR	982	982.00	20.00	0.05
91	SubSedGMNWR1	1173	1173.00	20.00	0.05
92	SubSedGMNWR2	1010	1010.00	20.00	0.05
93	SubSedGMNWR3	1326	1326.00	20.00	0.05
94	SubSedGMNWR4	1300	1300.00	20.00	0.05
95	SubSedGMNWR5	1046	1046.00	20.00	0.05
96	SubSedGMNWR6	1054	1054.00	20.00	0.05
97	SubSedGMNWR7	1239	1239.00	20.00	0.05

98	SubSedGMNWR8	1105	1105.00	20.00	0.05
99	SubSedGMNWR9	1469	1469.00	20.00	0.05
100	Deep_Res2end	110700	300	123	3
101	SedDeep_Res2end	738	300	123	0.02
102	SubSedDeep_Res2end	1845	300	123	0.05
103	ThirdSed_Deep_Res2end	1845	300	123	0.05
104	FourthSed_Deep_Res2end	1845	300	123	0.05
105	ThirdSed_Upstream_Res_2	10452	402	20	0.05
106	ThirdSed_Reservoir_2_first_leg	27104	220	77	0.05
107	ThirdSed_Res2_secleg	134000	670	100	0.05
108	ThirdSed_Res2mid	227550	740	123	0.05
109	ThirdSed_Res2end	644160	1220	240	0.05
110	ThirdSed_Res1from3	637560	1610	180	0.05
111	ThirdSed_Reservoir1	169769.6	742	104	0.05
112	FourthSed_Upstream_Res_2	10452	402	20	0.05
113	FourthSed_Reservoir_2_first_leg	27104	220	77	0.05
114	FourthSed_Res2_secleg	134000	670	100	0.05
115	FourthSed_Res2mid	227550	740	123	0.05
116	FourthSed_Res2end	644160	1220	240	0.05
117	FourthSed_Res1from3	637560	1610	180	0.05
118	FourthSed_Reservoir1	169769.6	742	104	0.05

Table A-2. Segment Types and Flow Characteristics

Segment	Segment Type	Bottom Segment	Slope	Bottom Roughness	Minimum Depth [m]
1	Surface	SedUpstream_Res_2	0	0.030	1.3
2	Surface	SedReservoir_2_first_leg	0	0.030	1.6
3	Surface	SedRes2_secleg	0	0.030	2
4	Surface	SedRes2mid	0	0.030	2.5
5	Surface	SedRes2end	0	0.030	2.2
6	Surface	SedRes1from3	0	0.030	2.2
7	Surface	SedReservoir1	0	0.030	2.2
8	Surface	SedSudburyRiverafterRes1	0.00288	0.03	0.02
9	Surface	SedSudburyRiverReach9	0.00008	0.04	0.02
10	Surface	SedSudburyRiverReach10	0.00008	0.04	0.02
11	Surface	SedSudburyRiverReach11	0.00008	0.04	0.02
12	Surface	SedSudburyRiverReach12	0.00008	0.04	0.02
13	Surface	SedSudburyRiverReach13	0.00211	0.04	0.02
14	Surface	SedSudburyRiverPond	0.0001	0.04	0.02
15	Surface	Sedstart_of_Saxonville_Pond	0.00011	0.04	0.02
16	Surface	SedmidSaxonvillePond	0.00011	0.04	0.02
17	Surface	SedendSaxonvillePond	0	0.04	0.02
18	Surface	SedSaxonvilleDam1	0.00715	0.04	0.02
19	Surface	SedSaxonvilleDam2	0.00021	0.04	0.02
20	Surface	SedSaxonvilleDam3	0.00032	0.04	0.02
21	Surface	SedSaxonvilleDam4	0.00032	0.04	0.02
22	Surface	SedHeardPondSwampMarsh	0.00032	0.04	0.02
23	Surface	SedMarshReach24	0.0001	0.04	0.02
24	Surface	SedUpofGMNWR	0.0001	0.045	0.02
25	Surface	SedGMNWR1	0.0001	0.050	0.02
26	Surface	SedGMNWR2	0.0001	0.050	0.02
27	Surface	SedGMNWR3	0.0001	0.050	0.02
28	Surface	SedGMNWR4	0.0001	0.050	0.02
29	Surface	SedGMNWR5	0.0001	0.050	0.02
30	Surface	SedGMNWR6	0.0001	0.050	0.02
31	Surface	SedGMNWR7	0.0001	0.050	0.02
32	Surface	SedGMNWR8	0.0001	0.050	0.02
33	Surface	SedGMNWR9	0.0001	0.050	0.02
34	Surface Benthic	SubSedUpstream_Res_2	0	231600	0.00
35	Surface Benthic	SubSedReservoir_2_first_leg	0	231600	0.00
36	Surface Benthic	SubSedRes2_secleg	0	450000	0.00
37	Surface Benthic	SubSedRes2mid	0	450000	0.00
38	Surface Benthic	SubSedRes2end	0	313200	0.00
39	Surface Benthic	SubSedRes1from3	0	313200	0.00
40	Surface Benthic	SubSedReservoir1	0	313200	0.00
41	Surface Benthic	SubSedSudburyRiverafterRes1	0.00288	1590000	0.00
42	Surface Benthic	SubSedSudburyRiverReach9	0.00008	1590000	0.00
43	Surface Benthic	SubSedSudburyRiverReach10	0.00008	1590000	0.00
44	Surface Benthic	SubSedSudburyRiverReach11	0.00008	1590000	0.00
45	Surface Benthic	SubSedSudburyRiverReach12	0.00008	1590000	0.00
46	Surface Benthic	SubSedSudburyRiverReach13	0.00211	1590000	0.00
47	Surface Benthic	SubSedSudburyRiverPond	0.0001	1590000	0.00

48	Surface Benthic	SubSedstart_of_Saxonville_Pond	0.00011	294000	0.00
49	Surface Benthic	SubSedmidSaxonvillePond	0.00011	294000	0.00
50	Surface Benthic	SubSedendSaxonvillePond	0	294000	0.00
51	Surface Benthic	SubSedSaxonvilleDam1	0.00715	1590000	0.00
52	Surface Benthic	SubSedSaxonvilleDam2	0.00021	1590000	0.00
53	Surface Benthic	SubSedSaxonvilleDam3	0.00032	1590000	0.00
54	Surface Benthic	SubSedSaxonvilleDam4	0.00032	1590000	0.00
55	Surface Benthic	SubSedHeardPondSwampMarsh	0.00032	1590000	0.00
56	Surface Benthic	SubSedMarshReach24	0.0001	1590000	0.00
57	Surface Benthic	SubSedUpofGMNWR	0.0001	1590000	0.00
58	Surface Benthic	SubSedGMNWR1	0.0001	446400	0.00
59	Surface Benthic	SubSedGMNWR2	0.0001	446400	0.00
60	Surface Benthic	SubSedGMNWR3	0.0001	446400	0.00
61	Surface Benthic	SubSedGMNWR4	0.0001	446400	0.00
62	Surface Benthic	SubSedGMNWR5	0.0001	446400	0.00
63	Surface Benthic	SubSedGMNWR6	0.0001	446400	0.00
64	Surface Benthic	SubSedGMNWR7	0.0001	446400	0.00
65	Surface Benthic	SubSedGMNWR8	0.0001	446400	0.00
66	Surface Benthic	SubSedGMNWR9	0.0001	446400	0.00
67	Subsurface Benthic	ThirdSed_Upstream_Res_2	0	600000	0.00
68	Subsurface Benthic	ThirdSed_Reservoir_2_first_leg	0	600000	0.00
69	Subsurface Benthic	ThirdSed_Res2_secleg	0	600000	0.00
70	Subsurface Benthic	ThirdSed_Res2mid	0	600000	0.00
71	Subsurface Benthic	ThirdSed_Res2end	0	600000	0.00
72	Subsurface Benthic	ThirdSed_Res1from3	0	600000	0.00
73	Subsurface Benthic	ThirdSed_Reservoir1	0	600000	0.00
74	Subsurface Benthic	None	0.00288	600000	0.00
75	Subsurface Benthic	None	0.00008	600000	0.00
76	Subsurface Benthic	None	0.00008	600000	0.00
77	Subsurface Benthic	None	0.00008	600000	0.00
78	Subsurface Benthic	None	0.00008	600000	0.00
79	Subsurface Benthic	None	0.00211	600000	0.00
80	Subsurface Benthic	None	0.0001	600000	0.00
81	Subsurface Benthic	None	0.00011	600000	0.00
82	Subsurface Benthic	None	0.00011	600000	0.00
83	Subsurface Benthic	None	0	600000	0.00
84	Subsurface Benthic	None	0.00715	600000	0.00
85	Subsurface Benthic	None	0.00021	600000	0.00
86	Subsurface Benthic	None	0.00032	600000	0.00
87	Subsurface Benthic	None	0.00032	600000	0.00
88	Subsurface Benthic	None	0.00032	600000	0.00
89	Subsurface Benthic	None	0.0001	600000	0.00
90	Subsurface Benthic	None	0.0001	600000	0.00
91	Subsurface Benthic	None	0.0001	600000	0.00
92	Subsurface Benthic	None	0.0001	600000	0.00
93	Subsurface Benthic	None	0.0001	600000	0.00
94	Subsurface Benthic	None	0.0001	600000	0.00
95	Subsurface Benthic	None	0.0001	600000	0.00
96	Subsurface Benthic	None	0.0001	600000	0.00
97	Subsurface Benthic	None	0.0001	600000	0.00

98	Subsurface Benthic	None	0.0001	600000	0.00
99	Subsurface Benthic	None	0.0001	600000	0.00
100	Surface	SedDeep_Res2end	0	0	3.00
101	Surface Benthic	SubSedDeep_Res2end	0.0008	375000	0.00
102	Subsurface Benthic	ThirdSed_Deep_Res2end	0.0008	600000	0.00
103	Subsurface Benthic	FourthSed_Deep_Res2end	0.0008	750000	0.00
104	Subsurface Benthic	none	0.0008	1000000	0.00
105	Subsurface Benthic	FourthSed_Upstream_Res_2	0	750000	0.00
106	Subsurface Benthic	FourthSed_Reservoir_2_first_leg	0.0008	750000	0.00
107	Subsurface Benthic	FourthSed_Res2_secleg	0.0008	750000	0.00
108	Subsurface Benthic	FourthSed_Res2mid	0.0008	750000	0.00
109	Subsurface Benthic	FourthSed_Res2end	0.0001	750000	0.00
110	Subsurface Benthic	FourthSed_Res1from3	0.0008	750000	0.00
111	Subsurface Benthic	FourthSed_Reservoir1	0.0001	750000	0.00
112	Subsurface Benthic	none	0	1000000	0.00
113	Subsurface Benthic	none	0.0008	1000000	0.00
114	Subsurface Benthic	none	0.0008	1000000	0.00
115	Subsurface Benthic	none	0.0008	1000000	0.00
116	Subsurface Benthic	none	0.0001	1000000	0.00
117	Subsurface Benthic	none	0.0008	1000000	0.00
118	Subsurface Benthic	none	0.0001	1000000	0.00

Table A-3. Initial Conditions, Mercury and Solids Concentrations

Segment	Description	HgT	Hg(0)	Hg(II)	MeHg	Silts and Fines (mg/L)	Sands (mg/L)	Organic Matter (mg/L)
1	Upstream_Res_2	4.5	0.0	4.2	0.1	2	0	0
2	Reservoir_2_first_leg	4.5	0.0	4.2	0.1	2	0	0
3	Res2mid	4.0	0.0	3.8	0.1	2	0	0
4	Res2end	3.3	0.0	3.1	0.1	2	0	0
5	Reservoir1fromRes2	2.8	0.0	2.6	0.1	2	0	0
6	Res1mid	1.4	0.0	1.3	0.1	2	0	0
7	Res1fromRes3	3.0	0.0	2.9	0.1	2	0	0
8	SudburyRiverafterRes1	3.0	0.0	2.9	0.1	2	0	0
9	SudburyRiverReach9	3.0	0.0	2.9	0.1	2	0	0
10	SudburyRiverReach10	3.0	0.0	2.9	0.1	2	0	0
11	SudburyRiverReach11	3.0	0.0	2.9	0.1	2	0	0
12	SudburyRiverReach12	3.0	0.0	2.9	0.1	2	0	0
13	SudburyRiverReach13	3.0	0.0	2.9	0.1	2	0	0
14	SudburyRiverPond	3.0	0.0	2.9	0.1	2	0	0
15	start_of_Saxonville_Pond	3.0	0.0	2.9	0.1	2	0	0
16	midSaxonvillePond	3.0	0.0	2.9	0.1	2	0	0
17	endSaxonvillePond	3.0	0.0	2.9	0.1	2	0	0
18	SaxonvilleDam1	3.0	0.0	2.9	0.1	2	0	0
19	SaxonvilleDam2	3.0	0.0	2.9	0.1	2	0	0
20	SaxonvilleDam3	3.0	0.0	2.9	0.1	2	0	0
21	SaxonvilleDam4	3.0	0.0	2.9	0.1	2	0	0
22	HeardPondSwampMarsh	3.0	0.0	2.9	0.1	2	0	0
23	MarshReach24	3.0	0.0	2.9	0.1	6	0	0
24	UpofGMNWR	7.0	0.0	6.8	0.1	6	0	0
25	GMNWR1	7.3	0.0	7.0	0.1	6	0	0
26	GMNWR2	9.0	0.0	8.8	0.1	6	0	0
27	GMNWR3	7.0	0.0	6.8	0.1	6	0	0
28	GMNWR4	7.3	0.0	7.0	0.1	6	0	0
29	GMNWR5	7.0	0.0	6.8	0.1	6	0	0
30	GMNWR6	7.0	0.0	6.8	0.1	6	0	0
31	GMNWR7	7.0	0.0	6.8	0.1	6	0	0
32	GMNWR8	7.0	0.0	6.8	0.1	6	0	0
33	GMNWR9	7.0	0.0	6.8	0.1	6	0	0
34	SedUpstream_Res_2	3,440.4	0.0	3,434.1	6.3	342,000	0	21,800
35	SedReservoir_2_first_leg	2,609.6	0.0	2,604.5	5.1	407,000	0	51,500
36	SedRes2mid	4,823.5	0.0	4,819.5	3.9	479,000	5,590	234,000
37	SedRes2end	12,922.9	0.0	12,918.7	4.2	265,000	52,500	502,000
38	SedReservoir1fromRes2	13,004.0	0.0	13,000.0	4.0	115,000	47,300	444,000
39	SedRes1mid	869.4	0.0	868.1	1.3	369,000	3,470	136,000
40	SedRes1fromRes3	7,883.0	0.0	7,880.7	2.3	144,000	41,200	358,000
41	SedSudburyRiverafterRes1	281.6	0.0	280.6	1.0	3	10	24

42	SedSudburyRiverReach9	43.5	0.0	43.3	0.2	99,000	10	68,800
43	SedSudburyRiverReach10	1,112.9	0.0	1,110.0	2.9	125,000	0	64,500
44	SedSudburyRiverReach11	2,520.5	0.0	2,515.0	5.5	155,000	10	83,400
45	SedSudburyRiverReach12	172.5	0.0	171.7	0.8	153,000	10	81,600
46	SedSudburyRiverReach13	943.0	0.0	941.4	1.6	2	0	32
47	SedSudburyRiverPond	1,171.2	0.0	1,168.3	2.9	630,000	35	88,100
48	Sedstart_of_Saxonville_Pond	211.6	0.0	210.8	0.8	652,000	276	159,000
49	SedmidSaxonvillePond	1,476.4	0.0	1,475.3	1.1	533,000	372	235,000
50	SedendSaxonvillePond	3,778.7	0.0	3,774.8	3.8	589,000	2,540	114,000
51	SedSaxonvilleDam1	35.4	0.0	35.3	0.1	4	0	10
52	SedSaxonvilleDam2	31.5	0.0	31.4	0.0	44	0	647
53	SedSaxonvilleDam3	353.8	0.0	353.4	0.4	10	0	248
54	SedSaxonvilleDam4	61.8	0.0	61.7	0.1	10	0	240
55	SedHeardPondSwampMarsh	1,890.3	0.0	1,881.1	9.2	268,000	10	106,000
56	SedMarshReach24	226.3	0.0	225.5	0.7	169,000	10	69,600
57	SedUpofGMNWR	6,727.0	0.0	6,721.1	5.9	257,000	10	60,000
58	SedGMNWR1	132.0	0.0	131.6	0.4	461,000	135	293,000
59	SedGMNWR2	96.2	0.0	95.9	0.3	478,000	179	321,000
60	SedGMNWR3	440.2	0.0	436.5	3.8	461,000	164	312,000
61	SedGMNWR4	1,294.3	0.0	1,283.0	11.2	455,000	156	311,000
62	SedGMNWR5	1,003.9	0.0	998.6	5.3	457,000	151	317,000
63	SedGMNWR6	1,195.5	0.0	1,191.0	4.5	454,000	135	316,000
64	SedGMNWR7	1,934.8	0.0	1,918.0	16.8	441,000	124	309,000
65	SedGMNWR8	119.4	0.0	119.1	0.2	452,000	88	314,000
66	SedGMNWR9	678.4	0.0	676.0	2.4	471,000	105	335,000
67	SubSedUpstream_Res_2	13,329.7	0.0	13,320.2	9.5	816,000	0	50,400
68	SubSedReservoir_2_first_leg	10,110.0	0.0	10,102.4	7.6	770,000	0	96,200
69	SubSedRes2mid	10,007.5	0.0	10,000.0	7.5	481,000	36,400	287,000
70	SubSedRes2end	4,582.5	0.0	4,555.8	26.7	332,000	88,400	364,000
71	SubSedReservoir1fromRes2	25,632.0	0.0	25,628.8	3.3	424,000	97,500	350,000
72	SubSedRes1mid	3,369.2	0.0	3,367.2	2.0	526,000	42,200	256,000
73	SubSedRes1fromRes3	15,538.2	0.0	15,536.4	1.8	295,000	92,200	363,000
74	SubSedSudburyRiverafterRes1	2,001.0	0.0	2,000.0	1.0	360,000	100,000	267,000
75	SubSedSudburyRiverReach9	2,001.0	0.0	2,000.0	1.0	323,000	100,000	230,000
76	SubSedSudburyRiverReach10	2,001.0	0.0	2,000.0	1.0	341,000	99,800	244,000
77	SubSedSudburyRiverReach11	2,001.0	0.0	2,000.0	1.0	352,000	99,700	257,000
78	SubSedSudburyRiverReach12	2,001.0	0.0	2,000.0	1.0	355,000	99,700	262,000
79	SubSedSudburyRiverReach13	2,001.0	0.0	2,000.0	1.0	360,000	100,000	267,000
80	SubSedSudburyRiverPond	2,001.0	0.0	2,000.0	1.0	310,000	75,200	165,000
81	SubSedstart_of_Saxonville_Pond	2,001.0	0.0	2,000.0	1.0	392,000	85,300	258,000
82	SubSedmidSaxonvillePond	2,001.0	0.0	2,000.0	1.0	363,000	96,000	280,000
83	SubSedendSaxonvillePond	2,001.0	0.0	2,000.0	1.0	697,000	24,600	172,000
84	SubSedSaxonvilleDam1	2,001.0	0.0	2,000.0	1.0	360,000	100,000	267,000
85	SubSedSaxonvilleDam2	2,001.0	0.0	2,000.0	1.0	342,000	100,000	248,000
86	SubSedSaxonvilleDam3	2,001.0	0.0	2,000.0	1.0	360,000	100,000	267,000
87	SubSedSaxonvilleDam4	2,001.0	0.0	2,000.0	1.0	360,000	100,000	267,000

88	SubSedHeardPondSwampMarsh	4,402.9	0.0	4,391.3	11.6	355,000	100,000	261,000
89	SubSedMarshReach24	4,002.0	0.0	4,000.0	2.0	358,000	100,000	264,000
90	SubSedUpofGMNWR	7,840.5	0.0	7,838.9	1.5	329,000	90,200	232,000
91	SubSedGMNWR1	1,503.0	0.0	1,500.0	3.0	368,000	97,100	266,000
92	SubSedGMNWR2	1,503.0	0.0	1,500.0	3.0	366,000	98,100	268,000
93	SubSedGMNWR3	1,503.0	0.0	1,500.0	3.0	364,000	98,600	268,000
94	SubSedGMNWR4	1,483.8	0.0	1,478.9	4.9	363,000	98,800	267,000
95	SubSedGMNWR5	1,503.0	0.0	1,500.0	3.0	362,000	98,900	267,000
96	SubSedGMNWR6	1,503.0	0.0	1,500.0	3.0	362,000	99,000	267,000
97	SubSedGMNWR7	1,712.3	0.0	1,704.5	7.7	362,000	99,200	267,000
98	SubSedGMNWR8	1,503.0	0.0	1,500.0	3.0	364,000	98,700	268,000
99	SubSedGMNWR9	1,503.0	0.0	1,500.0	3.0	362,000	99,300	267,000
100	Deep_Res2end	0.0	0.0	0.0	0.0	0	0	0
101	SedDeep_Res2end	21,032.6	0.0	21,026.2	6.4	108,000	3,010	514,000
102	SubSedDeep_Res2end	27,619.5	0.0	27,606.1	13.5	262,000	93,300	513,000
103	ThirdSed_Deep_Res2end	26,854.0	0.0	26,850.7	3.3	342,000	155,000	371,000
104	FourthSed_Deep_Res2end	21,738.0	0.0	21,736.9	1.1	409,000	216,000	332,000
105	ThirdSed_Upstream_Res_2	3,002.0	0.0	3,000.0	2.0	616,000	98,100	152,000
106	ThirdSed_Reservoir_2_first_leg	2,579.0	0.0	2,572.5	6.5	484,000	159,000	224,000
107	ThirdSed_Res2mid	3,832.0	0.0	3,819.5	12.5	310,000	287,000	270,000
108	ThirdSed_Res2end	837.5	0.0	817.8	19.8	426,000	174,000	267,000
109	ThirdSed_Reservoir1fromRes2	13,078.0	0.0	13,077.3	0.7	450,000	150,000	267,000
110	ThirdSed_Res1mid	3,002.0	0.0	3,000.0	2.0	449,000	149,000	267,000
111	ThirdSed_Res1fromRes3	3,002.0	0.0	3,000.0	2.0	450,000	150,000	268,000
112	FourthSed_Upstream_Res_2	3,002.0	0.0	3,000.0	2.0	509,000	172,000	251,000
113	FourthSed_Reservoir_2_first_leg	1,238.0	0.0	1,225.6	12.4	444,000	186,000	272,000
114	FourthSed_Res2mid	527.0	0.0	509.8	17.2	354,000	250,000	270,000
115	FourthSed_Res2end	3,550.0	0.0	3,545.2	4.9	384,000	216,000	267,000
116	FourthSed_Reservoir1fromRes2	3,080.5	0.0	3,078.7	1.9	384,000	216,000	267,000
117	FourthSed_Res1mid	3,002.0	0.0	3,000.0	2.0	388,000	216,000	267,000
118	FourthSed_Res1fromRes3	3,002.0	0.0	3,000.0	2.0	384,000	216,000	267,000

USGS Flow (cubic feet per second)

		Reservoir Reach				Wetlands Reach		
Drainage Area, mi ²	35.1	43.4	44.4	75.2		106.0	138.7	155.9
	ASHLAND	RT 135	ESTIMATE	ESTIMATE		SAXONVILLE	RT 20	RT 117
	Gage		Reservoir 2	Reservoir 1		Gage		Gage
DATE	1097480	109748221	OUTFLOW	OUTFLOW		1098530	1098800	1098820
		B*1.26	F*0.70					
10/1/2006	6.2	6.9	7.8	27		38.2	53	73
10/2/2006	8.1	9.1	10	22		32.4	46	87
10/3/2006	23.2	27	29	20		28.3	41	91
10/4/2006	18.8	22	24	34		48.3	65	91
10/5/2006	14.7	17	19	61		86.9	113	90
10/6/2006	9.5	11	12	46		66.5	88	97
10/7/2006	7.0	7.9	8.8	17		24.3	36	99
10/8/2006	7.5	8.5	9.4	14		19.6	31	91
10/9/2006	7.1	8	8.9	14		19.6	31	83
10/10/2006	7.1	8	8.9	13		19.3	30	75
10/11/2006	6.5	7.3	8.2	13		19.4	30	74
10/12/2006	34.2	40	43	113		162.1	206	204
10/13/2006	39.7	47	50	57		82.2	107	245
10/14/2006	37.5	44	47	43		62.0	83	260
10/15/2006	24.2	28	30	36		51.0	69	249
10/16/2006	17.1	20	21	41		57.7	78	220
10/17/2006	15.9	18	20	76		108.5	139	191
10/18/2006	13.5	15	16	78		110.5	143	182
10/19/2006	13.8	16	18	66		95.2	123	176
10/20/2006	12.9	15	16	66		94.8	123	183
10/21/2006	21.9	26	28	44		62.8	84	198
10/22/2006	22.7	27	29	32		46.4	63	190
10/23/2006	20.5	23	25	40		57.1	76	182
10/24/2006	18.6	22	24	66		95.4	123	170
10/25/2006	18.0	21	23	65		93.3	121	160
10/26/2006	23.0	27	29	65		93.0	121	148
10/27/2006	33.3	39	42	70		99.8	129	145
10/28/2006	59.7	72	76	171		244.1	306	190
10/29/2006	110.3	134	139	187		267.2	335	285
10/30/2006	94.6	115	120	157		224.4	282	321
10/31/2006	75.9	91	96	153		219.2	276	344
11/1/2006	55.1	66	69	139		198.5	251	348
11/2/2006	44.3	52	55	108		153.7	196	335
11/3/2006	38.6	46	49	58		83.2	108	317
11/4/2006	33.0	39	42	48		68.4	90	297
11/5/2006	28.6	34	37	43		61.4	81	273
11/6/2006	25.9	30	33	40		57.1	76	244
11/7/2006	24.5	28	30	38		55.1	74	221
11/8/2006	28.3	33	35	94		134.2	171	215
11/9/2006	66.1	79	83	216		307.9	385	302
11/10/2006	71.6	86	91	155		221.1	278	331
11/11/2006	68.5	83	87	87		124.1	159	359
								867.2

11/12/2006	52.5	63	67	85		121.9	156	363	878.5
11/13/2006	56.4	67	71	92		132.2	169	365	882.5
11/14/2006	88.1	106	111	248		354.5	442	418	1021.5
11/15/2006	96.1	116	121	241		344.2	429	442	1089.1
11/16/2006	88.4	106	111	222		316.8	396	467	1149.0
11/17/2006	129.2	157	163	338		482.8	600	535	1315.5
11/18/2006	149.1	183	188	328		469.0	583	551	1358.5
11/19/2006	123.7	151	156	295		421.1	524	571	1410.7
11/20/2006	91.4	110	115	260		371.7	464	579	1432.9
11/21/2006	74.0	89	93	219		313.4	391	563	1387.5
11/22/2006	65.8	79	83	228		325.2	406	543	1336.3
11/23/2006	62.3	74	78	262		373.9	466	531	1306.9
11/24/2006	158.5	194	199	326		466.2	579	595	1472.0
11/25/2006	174.2	214	219	331		472.9	588	623	1537.1
11/26/2006	145.5	179	184	304		435.3	541	651	1606.9
11/27/2006	116.4	141	146	270		385.9	481	655	1617.4
11/28/2006	101.9	124	129	265		379.4	472	631	1559.1
11/29/2006	94.4	114	118	189		270.2	338	603	1488.3
11/30/2006	90.9	110	115	148		211.0	266	575	1419.2
12/1/2006	88.9	107	112	148		212.3	267	543	1341.0
12/2/2006	104.4	126	131	174		249.1	313	527	1303.3
12/3/2006	108.5	131	136	152		216.6	273	511	1259.8
12/4/2006	100.8	122	127	161		230.4	289	495	1220.7
12/5/2006	88.6	107	112	192		274.3	343	471	1162.3
12/6/2006	84.0	101	106	182		260.2	326	447	1101.6
12/7/2006	81.1	98	102	183		262.1	328	426	1050.5
12/8/2006	76.2	91	96	174		248.9	313	405	995.7
12/9/2006	71.6	86	91	144		205.7	260	387	950.9
12/10/2006	72.6	88	92	141		201.3	253	370	909.3
12/11/2006	69.3	83	87	120		170.5	217	353	865.5
12/12/2006	66.0	79	83	84		119.7	154	337	828.3
12/13/2006	64.7	78	82	82		117.2	150	322	789.1
12/14/2006	67.7	82	86	84		119.6	154	309	756.8
12/15/2006	54.3	64	68	78		111.4	143	296	725.1
12/16/2006	49.0	58	62	72		102.8	133	282	691.2
12/17/2006	47.0	56	59	69		97.7	127	270	659.1
12/18/2006	45.8	55	58	68		96.6	126	255	624.0
12/19/2006	45.0	53	57	66		93.8	122	239	584.4
12/20/2006	44.1	52	55	64		91.3	118	227	552.1
12/21/2006	44.4	52	55	64		91.2	118	217	527.5
12/22/2006	43.0	51	54	75		106.6	138	205	499.0
12/23/2006	60.5	73	77	153		217.6	274	233	568.9
12/24/2006	78.0	94	98	148		211.2	266	269	656.7
12/25/2006	75.8	91	96	136		194.7	246	292	714.2
12/26/2006	79.8	96	101	181		258.4	324	328	803.7
12/27/2006	79.6	96	101	191		273.2	342	339	831.6
12/28/2006	74.0	89	93	181		258.2	324	353	866.0
12/29/2006	63.6	77	81	139		198.7	251	351	862.4
12/30/2006	56.6	68	72	81		116.0	149	343	841.6
12/31/2006	52.9	63	67	76		108.0	139	327	801.5
1/1/2007	64.7	78	82	111		158.8	202	334	818.9

1/2/2007	98.9	120	125	162		231.0	290	358	879.8
1/3/2007	100.8	122	127	225		320.7	401	377	926.6
1/4/2007	85.2	103	107	244		349.0	435	390	957.5
1/5/2007	72.4	86	91	174		248.5	313	396	974.6
1/6/2007	68.1	82	86	99		140.5	180	398	978.7
1/7/2007	63.5	75	79	90		128.9	165	384	944.4
1/8/2007	73.1	88	92	141		201.0	253	397	976.4
1/9/2007	96.9	117	122	185		264.0	331	410	1011.7
1/10/2007	94.7	115	120	197		280.9	352	414	1022.8
1/11/2007	77.5	93	97	192		274.0	343	418	1031.1
1/12/2007	70.0	84	88	172		246.2	309	414	1019.7
1/13/2007	67.3	80	84	98		140.1	178	399	982.2
1/14/2007	64.9	78	82	94		134.0	171	384	945.3
1/15/2007	80.1	96	101	134		192.4	242	394	969.6
1/16/2007	102.3	124	129	197		281.5	352	405	997.1
1/17/2007	95.5	116	121	274		392.0	488	406	1004.2
1/18/2007	75.7	91	96	224		319.9	400	410	1012.0
1/19/2007	70.9	85	89	113		162.0	338	410	1012.1
1/20/2007	71.0	85	89	92		130.9	301	399	981.1
1/21/2007	59.5	70	74	86		123.4	265	366	899.1
1/22/2007	59.6	72	76	98		140.0	240	345	847.8
1/23/2007	56.6	68	72	120		171.7	218	329	805.7
1/24/2007	54.6	66	69	153		217.8	274	315	772.3
1/25/2007	52.9	63	67	168		240.4	301	303	741.6
1/26/2007	47.4	56	59	134		191.7	242	284	694.5
1/27/2007	43.1	51	54	73		103.5	134	265	647.5
1/28/2007	41.9	50	53	71		101.1	131	250	610.5
1/29/2007	44.0	52	55	69		99.3	128	236	574.7
1/30/2007	41.9	50	53	67		96.3	124	220	534.6
1/31/2007	40.3	47	50	67		96.3	124	208	504.5
2/1/2007	39.0	46	49	64		92.1	119	193	467.7
2/2/2007	38.6	46	49	64		92.0	119	182	440.5
2/3/2007	34.1	40	43	66		95.0	123	178	430.5
2/4/2007	32.4	38	40	62		88.0	115	171	413.9
2/5/2007	31.1	36	39	58		83.2	108	162	390.7
2/6/2007	28.0	33	35	83		117.7	151	154	372.2
2/7/2007	25.5	29	32	138		196.6	249	156	375.2
2/8/2007	23.7	28	30	124		176.7	224	166	400.2
2/9/2007	22.5	26	28	90		127.5	164	170	409.9
2/10/2007	21.7	26	28	50		71.8	95	164	396.0
2/11/2007	21.4	24	26	47		67.1	89	150	360.3
2/12/2007	21.2	24	26	47		66.7	89	138	330.5
2/13/2007	21.2	24	26	46		65.9	88	131	312.9
2/14/2007	40.9	48	52	62		88.0	92	121	289.4
2/15/2007	77.2	93	97	79		112.5	145	115	273.8
2/16/2007	54.9	66	69	122		175.4	222	139	333.3
2/17/2007	36.6	44	47	176		251.5	316	154	372.0
2/18/2007	30.5	36	39	160		228.3	287	157	378.2
2/19/2007	29.8	35	38	130		185.4	234	154	371.2
2/20/2007	26.5	32	34	111		159.1	202	151	364.1
2/21/2007	22.9	27	29	92		131.1	167	150	360.6

2/22/2007	23.1	27	29	78		111.0	143	144	345.1
2/23/2007	23.5	28	30	69		99.3	128	142	342.5
2/24/2007	24.1	28	30	69		97.9	127	141	338.2
2/25/2007	23.8	28	30	97		138.5	177	140	335.6
2/26/2007	23.7	28	30	118		168.2	213	138	331.9
2/27/2007	23.3	27	29	85		120.6	155	140	336.2
2/28/2007	23.3	27	29	65		92.6	121	146	350.6
3/1/2007	24.1	28	30	93		132.5	163	158	380.9
3/2/2007	73.3	88	92	299		427.1	531	238	581.5
3/3/2007	151.8	186	192	365		521.2	647	380	934.0
3/4/2007	166.8	205	210	359		513.0	637	475	1168.1
3/5/2007	114.6	140	145	310		443.0	551	527	1301.6
3/6/2007	86.9	105	110	249		356.0	444	523	1291.4
3/7/2007	67.0	80	84	197		282.4	353	499	1228.7
3/8/2007	54.9	66	69	140		200.4	252	467	1146.8
3/9/2007	48.3	57	60	83		119.4	153	430	1055.8
3/10/2007	45.0	53	57	81		115.6	149	389	956.8
3/11/2007	72.3	86	91	130		186.3	235	398	977.6
3/12/2007	101.8	124	129	170		243.4	305	406	1003.2
3/13/2007	102.3	124	129	228		325.6	407	418	1026.6
3/14/2007	111.0	135	140	258		369.0	460	451	1112.7
3/15/2007	124.4	151	156	316		451.2	561	483	1187.5
3/16/2007	114.7	140	145	314		447.8	557	495	1222.6
3/17/2007	84.0	101	106	346		493.6	614	519	1283.0
3/18/2007	77.7	94	98	274		390.7	487	523	1292.9
3/19/2007	83.5	100	105	160		229.0	288	515	1270.1
3/20/2007	85.1	103	107	159		226.8	285	495	1223.9
3/21/2007	88.9	107	112	155		221.8	279	471	1161.8
3/22/2007	87.6	106	111	182		260.4	326	467	1148.5
3/23/2007	145.7	179	184	300		428.2	533	491	1214.5
3/24/2007	168.3	207	212	347		495.8	616	527	1303.0
3/25/2007	198.2	245	249	384		548.6	681	587	1453.0
3/26/2007	208.0	257	262	405		578.3	717	639	1582.4
3/27/2007	208.2	257	262	446		637.1	790	683	1693.3
3/28/2007	216.0	267	272	446		636.6	790	715	1773.9
3/29/2007	193.0	238	243	421		601.8	747	731	1813.6
3/30/2007	162.0	199	204	356		508.8	632	739	1832.8
3/31/2007	142.0	174	179	234		334.4	417	727	1797.3
4/1/2007	127.6	156	161	203		290.2	363	695	1722.0
4/2/2007	137.8	169	174	260		372.3	464	659	1633.6
4/3/2007	146.8	180	185	342		489.3	608	627	1546.5
4/4/2007	138.5	170	175	366		522.9	649	611	1512.8
4/5/2007	210.0	260	265	479		684.2	847	679	1679.6
4/6/2007	236.6	294	299	457		652.9	809	731	1811.2
4/7/2007	197.8	245	249	404		577.4	716	768	1898.0
4/8/2007	157.1	193	198	363		517.6	643	772	1912.1
4/9/2007	133.3	162	168	318		454.2	565	747	1845.6
4/10/2007	119.2	145	150	277		395.7	493	707	1753.6
4/11/2007	109.8	134	139	225		322.2	402	667	1648.6
4/12/2007	105.0	127	132	223		319.4	399	635	1574.1
4/13/2007	169.0	208	213	337		480.9	598	647	1597.1

4/14/2007	188.1	232	237	354		504.6	627	651	1609.0
4/15/2007	162.6	200	205	386		551.4	684	691	1714.3
4/16/2007	462.7	586	583	763		1091.6	1350	980	2428.0
4/17/2007	616.4	786	776	875		1252.7	1540	1130	2807.6
4/18/2007	534.1	678	673	882		1260.1	1560	1330	3306.4
4/19/2007	421.0	531	530	798		1143.2	1410	1430	3550.0
4/20/2007	331.3	415	417	728		1038.0	1290	1450	3594.6
4/21/2007	246.5	306	310	663		946.6	1170	1410	3493.6
4/22/2007	208.3	257	262	620		886.5	1100	1350	3336.1
4/23/2007	181.1	223	228	582		831.7	1030	1270	3147.1
4/24/2007	161.2	198	203	545		777.6	963	1180	2934.9
4/25/2007	145.4	178	183	512		732.5	906	1100	2725.3
4/26/2007	143.1	175	180	449		641.3	794	1030	2548.9
4/27/2007	158.2	194	199	430		613.7	761	980	2434.8
4/28/2007	191.0	236	241	488		697.2	863	936	2323.4
4/29/2007	185.7	229	234	476		679.5	842	896	2219.4
4/30/2007	164.0	202	207	448		639.8	793	868	2149.6
5/1/2007	141.6	174	179	416		594.1	737	828	2048.2
5/2/2007	129.3	157	163	393		562.4	697	784	1944.5
5/3/2007	117.5	144	149	355		506.5	630	743	1839.2
5/4/2007	103.9	126	131	329		469.7	584	699	1730.9
5/5/2007	95.4	115	120	299		427.5	531	651	1614.8
5/6/2007	89.3	107	112	287		410.3	510	603	1490.1
5/7/2007	77.5	94	98	270		385.0	480	563	1393.1
5/8/2007	63.8	77	81	246		350.7	438	527	1301.7
5/9/2007	56.6	68	72	223		317.6	397	491	1208.9
5/10/2007	51.2	61	64	209		298.8	374	455	1123.1
5/11/2007	48.4	57	60	220		313.9	392	447	1100.0
5/12/2007	52.0	62	66	213		304.1	380	442	1092.0
5/13/2007	45.5	53	57	202		288.0	360	422	1046.3
5/14/2007	40.5	47	50	197		280.6	352	402	1001.5
5/15/2007	38.6	46	49	190		270.5	340	379	950.3
5/16/2007	38.4	45	48	237		339.0	423	381	953.3
5/17/2007	155.0	190	195	387		552.7	686	451	1114.3
5/18/2007	176.0	217	222	480		685.2	849	511	1264.4
5/19/2007	252.2	313	318	556		793.8	983	667	1651.7
5/20/2007	247.7	308	312	564		805.4	996	784	1943.5
5/21/2007	216.7	269	273	551		787.5	974	856	2122.6
5/22/2007	150.2	184	189	481		686.9	851	888	2196.0
5/23/2007	120.6	147	152	370		528.5	657	880	2183.7
5/24/2007	98.2	119	123	246		351.4	438	844	2088.1
5/25/2007	83.3	100	105	293		418.8	522	780	1932.4
5/26/2007	79.1	95	100	329		469.9	584	715	1766.6
5/27/2007	63.0	75	79	309		441.1	549	647	1601.1
5/28/2007	52.5	63	67	293		418.3	520	595	1468.9
5/29/2007	48.1	57	60	279		398.8	497	543	1341.2
5/30/2007	42.1	50	53	273		389.6	486	503	1240.3
5/31/2007	37.8	45	48	215		306.6	384	467	1145.8
6/1/2007	38.2	45	48	134		191.0	241	434	1076.1
6/2/2007	43.1	51	54	130		186.5	235	405	1006.9
6/3/2007	39.1	46	49	122		173.6	220	369	928.2

6/4/2007	58.1	69	73	197		282.4	353	383	959.6
6/5/2007	111.8	136	141	238		339.7	424	434	1075.2
6/6/2007	102.2	124	129	242		346.3	432	455	1119.0
6/7/2007	75.4	90	94	208		296.8	372	459	1127.5
6/8/2007	60.0	72	76	175		250.2	314	438	1083.4
6/9/2007	54.4	64	68	188		267.8	336	418	1039.0
6/10/2007	96.9	117	122	248		354.5	442	414	1032.0
6/11/2007	101.4	122	127	315		449.7	560	422	1047.9
6/12/2007	77.7	94	98	298		425.3	529	426	1061.3
6/13/2007	59.2	70	74	251		358.9	448	418	1032.9
6/14/2007	59.7	72	76	241		343.9	429	396	986.0
6/15/2007	48.3	57	60	258		368.6	460	376	942.1
6/16/2007	37.2	44	47	199		284.0	356	358	901.6
6/17/2007	31.1	36	39	141		200.9	253	336	853.3
6/18/2007	27.1	32	34	114		163.3	207	308	790.5
6/19/2007	25.2	29	32	150		214.3	269	280	726.8
6/20/2007	25.9	30	33	69		99.3	128	253	667.7
6/21/2007	24.3	28	30	59		84.1	110	231	616.2
6/22/2007	28.2	33	35	91		130.1	166	209	563.0
6/23/2007	25.4	29	32	154		220.0	277	191	514.1
6/24/2007	23.0	27	29	137		195.6	247	181	486.7
6/25/2007	21.0	24	26	134		192.4	242	173	464.5
6/26/2007	18.3	21	23	132		188.0	238	164	439.5
6/27/2007	24.8	29	32	105		150.5	191	158	419.4
6/28/2007	20.1	23	25	34		48.6	67	151	402.1
6/29/2007	14.7	17	19	41		58.4	78	135	356.5
6/30/2007	12.0	14	15	104		148.6	190	114	298.7
7/1/2007	10.5	13	14	104		147.7	188	106	276.0
7/2/2007	9.4	11	12	102		146.4	186	107	278.1
7/3/2007	8.5	9.6	11	100		143.0	182	105	272.0
7/4/2007	7.9	8.9	10	92		131.9	169	105	270.4
7/5/2007	7.9	8.9	10	98		140.3	178	123	324.5
7/6/2007	8.5	9.6	11	99		140.7	180	127	333.8
7/7/2007	8.0	9	10	92		132.3	169	123	324.5
7/8/2007	7.7	8.7	9.7	102		144.8	185	121	318.4
7/9/2007	14.7	17	19	183		262.1	328	125	328.5
7/10/2007	18.8	22	24	236		336.5	421	137	364.4
7/11/2007	26.6	32	34	195		278.1	348	150	400.0
7/12/2007	20.0	23	25	90		128.9	165	160	428.3
7/13/2007	13.3	15	16	27		39.3	54	160	428.1
7/14/2007	10.4	11	13	18		25.1	37	143	379.7
7/15/2007	9.1	10	11	15		21.5	33	124	324.9
7/16/2007	8.8	10	11	13		19.1	30	108	281.6
7/17/2007	9.3	11	12	13		19.0	30	86	220.2
7/18/2007	8.0	9	10	43		61.1	81	68	169.6
7/19/2007	7.6	8.6	9.6	138		196.8	249	66	165.2
7/20/2007	7.8	8.8	9.8	125		177.9	225	91	234.9
7/21/2007	7.4	8.3	9.3	116		165.3	209	101	262.6
7/22/2007	7.2	8.1	9.1	116		164.7	209	104	269.3
7/23/2007	7.0	7.9	8.8	116		165.4	209	103	266.5
7/24/2007	7.2	8.1	9.1	113		162.4	206	105	272.3

7/25/2007	7.0	7.9	8.8	62		89.2	116	102	264.7
7/26/2007	6.6	7.4	8.3	18		25.1	37	93	240.1
7/27/2007	5.9	6.6	7.4	12		16.8	27	77	194.4
7/28/2007	5.8	6.5	7.3	15		22.4	33	63	157.1
7/29/2007	5.2	5.8	6.6	18		25.5	38	45	108.2
7/30/2007	5.9	6.6	7.4	22		30.8	44	53	129.8
7/31/2007	8.5	9.6	11	22		30.7	44	64	157.6
8/1/2007	8.0	9	10	16		22.7	35	65	161.0
8/2/2007	7.5	8.5	9.4	13		19.3	30	62	151.6
8/3/2007	6.4	7.2	8.1	12		17.3	27	55	135.1
8/4/2007	6.2	6.9	7.8	9.8		14.2	24	48	114.7
8/5/2007	5.7	6.4	7.2	7.7		11.4	20	41	95.6
8/6/2007	5.4	6	6.8	10		14.8	25	40	94.1
8/7/2007	5.2	5.8	6.6	11		16.4	26	40	91.7
8/8/2007	5.4	6	6.8	13		19.4	30	46	109.4
8/9/2007	5.0	5.6	6.3	10		15.4	25	46	108.2
8/10/2007	4.9	5.5	6.2	9.8		13.6	24	43	100.8
8/11/2007	4.9	5.5	6.2	10		14.7	25	41	94.9
8/12/2007	4.9	5.5	6.2	9.1		12.8	22	40	93.2
8/13/2007	5.0	5.6	6.3	30		42.7	59	42	99.0
8/14/2007	4.9	5.5	6.2	99		141.3	180	42	97.5
8/15/2007	4.7	5.2	5.9	93		133.1	170	56	136.5
8/16/2007	4.6	5.1	5.8	93		133.2	170	66	164.4
8/17/2007	4.7	5.2	5.9	73		104.1	134	68	170.8
8/18/2007	4.5	5	5.7	15		22.3	33	65	162.3
8/19/2007	4.5	5	5.7	6.7		9.6	18	54	131.5
8/20/2007	4.9	5.5	6.2	5.5		7.8	16	42	99.7
8/21/2007	4.8	5.3	6	5.6		8.0	16	34	79.1
8/22/2007	4.5	5	5.7	5.7		8.1	16	30	66.0
8/23/2007	4.4	4.9	5.5	5.5		7.9	16	28	60.9
8/24/2007	4.4	4.9	5.5	6		8.6	17	28	62.9
8/25/2007	4.4	4.9	5.5	6.1		8.7	17	26	57.6
8/26/2007	3.9	4.3	4.9	5.6		8.0	16	24	51.0
8/27/2007	3.6	4	4.5	5		7.1	15	22	47.5
8/28/2007	3.5	3.9	4.4	4.5		6.4	14	22	45.7
8/29/2007	3.4	3.7	4.3	4.4		6.3	14	21	44.0
8/30/2007	3.3	3.6	4.2	4.1		5.9	14	22	46.4
8/31/2007	3.3	3.6	4.2	3.9		5.6	13	21	43.3
9/1/2007	3.0	3.3	3.8	3.6		5.2	13	20	39.9
9/2/2007	2.4	2.6	3	3.5		5.0	13	20	41.9
9/3/2007	2.2	2.4	2.8	3.5		5.0	13	20	40.4
9/4/2007	2.0	2.2	2.5	3.4		4.8	12	17	32.9
9/5/2007	1.8	1.9	2.3	3.2		4.6	12	16	29.3
9/6/2007	1.7	1.8	2.1	3.3		4.7	12	16	29.6
9/7/2007	1.6	1.7	2	3.4		4.8	12	16	29.6
9/8/2007	1.5	1.6	1.9	3.2		4.6	12	15	27.7
9/9/2007	1.7	1.8	2.1	3.3		4.7	12	24	51.4
9/10/2007	2.9	3.2	3.7	3.5		5.0	13	18	34.7
9/11/2007	5.7	6.4	7.2	35		49.9	68	42	99.8
9/12/2007	5.9	6.6	7.4	25		35.6	51	59	144.8
9/13/2007	4.4	4.9	5.5	26		36.9	52	59	146.1

9/14/2007	4.7	5.2	5.9	69		99.3	128	56	136.1
9/15/2007	4.8	5.3	6	22		31.1	44	60	146.3
9/16/2007	4.4	4.9	5.5	10		14.6	25	58	141.7
9/17/2007	4.4	4.9	5.5	16		22.6	35	46	111.2
9/18/2007	4.3	4.8	5.4	61		87.2	113	40	91.9
9/19/2007	4.1	4.5	5.2	52		75.3	99	47	111.4
9/20/2007	3.8	4.2	4.8	13		18.2	28	50	120.6
9/21/2007	3.5	3.9	4.4	7		10.2	19	43	102.0
9/22/2007	3.3	3.6	4.2	6.2		8.9	17	37	84.7
9/23/2007	3.3	3.6	4.2	6.1		8.7	17	31	70.4
9/24/2007	3.1	3.4	3.9	5.2		7.5	16	28	62.8
9/25/2007	2.9	3.2	3.7	4.8		6.9	15	27	60.1
9/26/2007	2.9	3.2	3.7	4.7		6.7	15	26	58.1
9/27/2007	2.7	3	3.4	4.5		6.4	14	26	55.2
9/28/2007	2.7	3	3.4	5.2		7.5	16	24	53.0
9/29/2007	2.6	2.8	3.3	4.9		7.0	15	23	47.9
9/30/2007	2.2	2.4	2.8	4.2		6.0	14	22	44.6
10/1/2007	2.4	2.6	3	4.1		5.9	35	67	39.8
10/2/2007	2.0	2.2	2.5	4.1		5.8	35	67	39.2
10/3/2007	1.8	1.9	2.3	4.2		6.0	35	67	39.8
10/4/2007	1.8	1.9	2.3	4.3		6.2	35	67	39.8
10/5/2007	1.5	1.6	1.9	4.3		6.1	35	67	39.0
10/6/2007	1.5	1.6	1.9	4.4		6.3	35	67	38.5
10/7/2007	1.4	1.5	1.8	4.5		6.4	35	67	38.4
10/8/2007	1.9	2.1	2.4	11		15.7	45	71	50.0
10/9/2007	1.8	1.9	2.3	7.7		11.0	40	70	47.3
10/10/2007	1.5	1.6	1.9	6.1		8.7	38	70	48.1
10/11/2007	1.4	1.5	1.8	6.2		8.9	38	70	49.3
10/12/2007	1.9	2.1	2.4	13		17.9	48	74	60.1
10/13/2007	1.8	1.9	2.3	9.1		13.4	42	79	73.6
10/14/2007	1.6	1.7	2	5.2		7.5	36	80	79.4
10/15/2007	1.4	1.5	1.8	4.6		6.6	35	79	76.4
10/16/2007	1.4	1.5	1.8	4.3		6.1	35	77	68.4
10/17/2007	1.3	1.4	1.6	4.1		5.9	35	75	64.1
10/18/2007	1.3	1.4	1.6	4.1		5.9	35	74	59.4
10/19/2007	1.1	1.2	1.4	9.8		13.6	43	76	64.5
10/20/2007	6.4	7.2	8.1	39		55.8	88	99	134.4
10/21/2007	6.3	7.1	7.9	14		19.9	50	98	132.3
10/22/2007	6.1	6.8	7.7	9.8		14.2	43	102	143.9
10/23/2007	6.2	6.9	7.8	9.8		14.2	43	100	137.8
10/24/2007	5.0	5.6	6.3	10		15.4	44	96	124.5
10/25/2007	4.8	5.3	6	9.1		13.1	42	93	116.5
10/26/2007	4.6	5.1	5.8	8.4		11.8	41	84	90.3
10/27/2007	5.8	6.5	7.3	18		25.5	55	83	86.4
10/28/2007	8.4	9.5	11	16		22.7	53	91	109.9
10/29/2007	8.4	9.5	11	10		15.2	44	91	109.9
10/30/2007	8.7	9.8	11	9.8		14.5	43	90	106.9
10/31/2007	9.4	11	12	11		15.5	45	88	101.6
11/1/2007	6.6	7.4	8.3	11		16.4	45	87	99.9
11/2/2007	6.2	6.9	7.8	57		80.9	114	85	92.8
11/3/2007	6.8	7.6	8.6	200		285.9	331	100	136.9

11/4/2007	18.0	21	23	156		223.3	265	151	289.5
11/5/2007	14.2	16	18	52		75.2	108	162	322.7
11/6/2007	16.5	18	20	64		91.3	125	159	314.3
11/7/2007	22.2	26	28	50		72.2	105	155	299.5
11/8/2007	20.7	24	26	24		35.1	66	150	286.5
11/9/2007	17.6	21	23	20		28.8	59	140	256.0
11/10/2007	16.7	20	21	18		24.8	55	126	214.8
11/11/2007	17.2	20	21	18		24.6	55	120	196.3
11/12/2007	12.5	14	15	15		22.1	52	113	176.9
11/13/2007	10.8	13	14	19		27.5	57	109	163.6
11/14/2007	9.4	11	12	15		22.1	52	108	162.1
11/15/2007	11.9	14	15	29		40.6	72	109	165.3
11/16/2007	20.6	24	26	43		61.7	94	124	208.3
11/17/2007	23.2	27	29	26		37.3	68	134	238.5
11/18/2007	20.7	24	26	23		33.0	63	134	239.0
11/19/2007	16.8	20	21	22		30.9	61	127	218.4
11/20/2007	14.1	16	18	20		28.8	59	123	206.5
11/21/2007	12.5	15	16	18		26.1	56	118	191.6
11/22/2007	12.9	15	16	17		23.7	54	114	180.1
11/23/2007	12.6	15	16	17		24.1	54	112	172.2
11/24/2007	11.5	13	14	13		19.3	49	108	162.1
11/25/2007	10.6	13	14	13		18.9	49	104	148.4
11/26/2007	11.6	14	15	28		40.4	71	103	146.1
11/27/2007	14.7	17	19	75		106.6	142	111	168.8
11/28/2007	16.3	18	20	73		103.7	139	118	189.7
11/29/2007	15.2	17	19	71		102.2	136	127	218.7
11/30/2007	14.6	17	19	60		85.1	118	133	236.0
12/1/2007	12.7	15	16	22		31.3	61	128	222.1
12/2/2007	10.6	13	14	14		19.7	50	121	200.4
12/3/2007	12.0	14	15	20		27.9	58	114	179.5
12/4/2007	19.3	22	24	21		30.1	60	109	162.8
12/5/2007	13.6	16	18	19		26.9	57	106	155.3
12/6/2007	10.2	11	13	16		23.2	53	104	149.7
12/7/2007	9.3	11	12	14		19.6	50	103	145.1
12/8/2007	9.0	10	11	14		20.1	50	101	140.4
12/9/2007	9.4	11	12	14		19.5	50	98	131.3
12/10/2007	10.1	11	13	15		21.8	52	96	126.2
12/11/2007	10.9	13	14	15		21.8	52	97	129.2
12/12/2007	13.8	16	18	19		27.5	57	100	138.2
12/13/2007	19.1	22	24	26		37.1	68	102	144.4
12/14/2007	20.0	23	25	29		42.1	73	105	151.7
12/15/2007	26.4	30	33	25		35.8	67	112	173.0
12/16/2007	87.1	105	110	71		102.4	136	112	174.1
12/17/2007	42.9	51	54	55		78.5	111	118	190.7
12/18/2007	32.8	39	42	90		129.5	165	125	210.8
12/19/2007	28.8	34	37	90		127.8	164	134	238.4
12/20/2007	28.5	33	35	95		136.4	172	141	261.1
12/21/2007	26.0	30	33	87		124.2	160	144	268.9
12/22/2007	25.2	29	32	83		118.2	153	146	274.7
12/23/2007	26.5	30	33	79		113.3	148	147	277.7
12/24/2007	53.7	64	68	125		179.0	218	169	343.6

12/25/2007	49.6	59	63	108		154.3	192	186	394.9
12/26/2007	47.1	56	59	100		143.2	180	196	424.1
12/27/2007	57.6	69	73	130		185.2	224	202	442.3
12/28/2007	56.1	67	71	130		185.8	225	212	469.5
12/29/2007	58.7	70	74	136		194.5	235	224	507.7
12/30/2007	57.4	68	72	134		192.0	232	230	524.5
12/31/2007	56.4	67	71	148		211.4	252	235	539.8
1/1/2008	53.1	63	67	139		198.8	239	237	545.8
1/2/2008	47.9	57	60	129		183.5	223	236	543.5
1/3/2008	70.3	84	88	108		154.6	193	232	529.9
1/4/2008	57.8	69	73	99		142.1	179	222	502.5
1/5/2008	32.4	38	40	94		135.3	171	202	441.5
1/6/2008	29.4	34	37	92		130.7	167	195	420.6
1/7/2008	29.9	35	38	92		131.2	167	189	403.6
1/8/2008	35.9	42	45	98		139.9	177	192	411.9
1/9/2008	65.9	79	83	128		182.7	222	213	473.5
1/10/2008	80.0	96	101	152		217.1	258	246	572.6
1/11/2008	132.6	162	168	244		348.0	397	307	753.5
1/12/2008	155.3	190	195	295		421.0	474	374	955.7
1/13/2008	132.4	161	166	255		363.7	414	399	1032.5
1/14/2008	100.5	121	126	279		398.4	450	423	1095.5
1/15/2008	87.8	106	111	330		471.9	528	433	1126.9
1/16/2008	80.5	98	102	313		447.0	502	426	1114.9
1/17/2008	69.4	83	87	214		306.0	352	409	1061.7
1/18/2008	77.6	94	98	232		331.9	380	419	1085.1
1/19/2008	81.5	98	102	183		262.5	306	416	1083.8
1/20/2008	73.6	89	93	168		240.0	283	403	1038.7
1/21/2008	64.3	77	81	148		212.4	253	377	964.3
1/22/2008	51.9	62	66	136		194.6	235	353	891.9
1/23/2008	48.8	58	62	125		179.1	218	333	833.3
1/24/2008	45.2	53	57	79		113.1	148	313	771.5
1/25/2008	40.7	48	52	77		109.7	145	285	689.3
1/26/2008	36.8	44	47	96		136.7	174	264	627.5
1/27/2008	36.1	42	45	95		135.7	172	245	570.3
1/28/2008	35.4	41	44	86		122.6	159	223	503.7
1/29/2008	34.5	40	43	90		128.2	164	223	503.4
1/30/2008	39.9	47	50	86		123.2	159	219	491.7
1/31/2008	43.2	51	54	65		93.1	127	215	479.9
2/1/2008	63.5	75	79	107		152.7	190	225	509.2
2/2/2008	162.0	201.0	204.0	251		358.2	408	313	771.8
2/3/2008	146.0	181.0	184.0	212		302.9	349	359	909.2
2/4/2008	107.9	131	136	235		336.0	384	403	1038.0
2/5/2008	116.7	142	147	345		493.5	550	440	1153.9
2/6/2008	167.7	207	212	412		588.9	652	500	1326.6
2/7/2008	313.1	392	394	612		873.6	954	621	1690.1
2/8/2008	289.0	358.0	364.0	556		794.8	870	694	1913.3
2/9/2008	202.0	250.0	255.0	507		724.4	795	748	2069.4
2/10/2008	188.4	232	237	470		671.9	740	775	2150.3
2/11/2008	154.5	190	195	440		628.2	693	728	2010.2
2/12/2008	139.0	170	175	443		633.3	699	711	1963.7
2/13/2008	226.4	280	285	555		792.6	868	745	2057.2

2/14/2008	384.8	485	485	735		1050.4	1140	842	2354.8
2/15/2008	372.7	469	470	672		960.1	1040	889	2486.3
2/16/2008	292.8	366	369	628		896.7	978	912	2557.9
2/17/2008	222.6	276	281	568		812.1	888	926	2604.5
2/18/2008	343.6	432	433	670		957.1	1040	963	2708.1
2/19/2008	427.5	539	538	742		1060.1	1150	1010	2864.4
2/20/2008	343.5	432	433	694		992.0	1080	1050	2956.2
2/21/2008	253.1	315	319	602		860.1	939	1040	2944.3
2/22/2008	203.5	252	257	557		796.0	871	1010	2837.3
2/23/2008	172.4	212	217	475		677.9	746	963	2705.5
2/24/2008	170.9	210	215	428		611.6	676	902	2532.8
2/25/2008	158.0	194	199	374		535.3	595	842	2346.7
2/26/2008	150.5	184	189	326		465.3	521	785	2179.8
2/27/2008	184.0	227	232	383		546.9	608	771	2139.5
2/28/2008	172.0	212	217	415		592.7	656	738	2037.0
2/29/2008	144.9	178	183	340		486.4	543	708	1951.1
3/1/2008	133.2	162	168	379		541.3	601	688	1885.1
3/2/2008	127.4	155	160	360		514.7	574	654	1791.9
3/3/2008	121.6	149	154	336		480.0	537	627	1709.0
3/4/2008	141.0	173	178	340		484.6	542	617	1680.0
3/5/2008	257.9	321	325	495		707.5	777	698	1916.8
3/6/2008	279.5	348	352	550		785.2	860	758	2099.5
3/7/2008	230.0	285	290	573		819.3	896	808	2252.9
3/8/2008	345.5	434	436	626		895.5	976	932	2618.0
3/9/2008	507.4	643	639	791		1134.3	1230	1070	3024.6
3/10/2008	397.1	500	500	728		1042.3	1130	1110	3164.8
3/11/2008	292.0	365	368	654		934.6	1020	1140	3244.0
3/12/2008	242.0	301	305	645		921.2	1000	1130	3205.8
3/13/2008	211.4	261	266	628		896.6	978	1090	3090.4
3/14/2008	188.1	232	237	588		840.2	918	1040	2938.0
3/15/2008	182.8	226	231	584		833.7	912	996	2807.9
3/16/2008	173.0	213	218	556		795.2	870	956	2691.3
3/17/2008	157.6	194	199	503		718.1	789	912	2560.9
3/18/2008	142.7	175	180	417		595.7	660	869	2432.3
3/19/2008	140.0	171	176	376		536.8	597	825	2304.1
3/20/2008	180.3	222	227	441		630.1	696	818	2280.9
3/21/2008	177.4	218	223	421		602.3	666	795	2214.6
3/22/2008	155.8	191	197	396		565.6	628	778	2162.0
3/23/2008	135.3	165	170	371		529.5	590	751	2078.1
3/24/2008	116.8	142	147	359		513.3	572	714	1965.1
3/25/2008	91.7	111	116	386		551.6	613	674	1846.1
3/26/2008	89.1	107	112	392		559.5	621	644	1762.5
3/27/2008	86.8	105	110	344		492.3	549	614	1667.1
3/28/2008	94.2	114	118	344		491.6	549	597	1622.3
3/29/2008	95.8	116	121	344		490.8	548	587	1593.2
3/30/2008	88.3	106	111	329		470.2	526	577	1558.4
3/31/2008	84.1	101	106	325		463.8	520	560	1508.0
4/1/2008	77.2	93.0	97	353		503.8	562.0	557.0	1497
4/2/2008	90.2	109.0	113	388		554.3	615.0	550.0	1477
4/3/2008	83.2	100.0	105	304		435.1	489.0	543.0	1457
4/4/2008	94.3	114.0	118	386		550.8	612.0	550.0	1481

4/5/2008	110.7	135.0	140	421		601.8	666.0	567.0	1527
4/6/2008	105.6	129.0	134	407		581.8	645.0	574.0	1552
4/7/2008	91.4	110.0	115	369		526.5	586.0	580.0	1571
4/8/2008	79.2	95.0	100	322		460.2	516.0	577.0	1556
4/9/2008	72.3	86.0	91	340		485.0	542.0	560.0	1512
4/10/2008	66.3	79.0	83	329		470.2	526.0	537.0	1443
4/11/2008	61.0	73.0	77	317		452.9	508.0	513.0	1370
4/12/2008	73.8	89.0	93	354		505.9	564.0	520.0	1391
4/13/2008	95.3	115.0	120	379		541.9	602.0	517.0	1380
4/14/2008	87.7	106.0	111	363		517.8	577.0	513.0	1367
4/15/2008	74.4	89.0	93	344		492.3	549.0	513.0	1367
4/16/2008	65.6	79.0	83	327		466.7	523.0	503.0	1340
4/17/2008	59.6	72.0	76	314		447.9	503.0	486.0	1293
4/18/2008	54.5	66.0	69	300		428.9	483.0	466.0	1229
4/19/2008	48.7	58.0	62	289		413.2	466.0	446.0	1170
4/20/2008	45.8	55.0	58	279		398.4	450.0	426.0	1106
4/21/2008	42.2	50.0	53	274		391.5	442.0	406.0	1055
4/22/2008	37.7	45.0	48	265		379.5	430.0	393.0	1010
4/23/2008	36.4	42.0	45	261		373.1	423.0	380.0	974
4/24/2008	38.4	45.0	48	256		365.6	416.0	362.0	920
4/25/2008	37.3	44.0	47	242		344.5	394.0	351.0	887
4/26/2008	29.4	34.0	37	221		315.9	363.0	335.0	839
4/27/2008	25.6	30.0	33	215		307.1	354.0	322.0	799
4/28/2008	32.2	38.0	40	251		359.2	409.0	321.0	797
4/29/2008	106.1	129.0	134	380		542.9	603.0	396.0	1018
4/30/2008	134.3	164.0	169	430		614.7	680.0	456.0	1198
5/1/2008	101.9	124.0	129	409		584.0	647.0	503.0	1343
5/2/2008	75.9	91.0	96	381		543.6	604.0	537.0	1437
5/3/2008	67.7	82.0	86	362		516.6	576.0	543.0	1461
5/4/2008	65.8	79.0	83	351		502.2	560.0	543.0	1464
5/5/2008	64.8	78.0	82	309		441.8	496.0	537.0	1444
5/6/2008	59.7	72.0	76	235		336.4	384.0	523.0	1404
5/7/2008	54.0	64.0	68	121		173.3	212.0	503.0	1342
5/8/2008	48.8	58.0	62	111		158.1	196.0	473.0	1249
5/9/2008	43.8	52.0	55	121		172.6	212.0	429.0	1122
5/10/2008	43.2	51.0	54	122		174.7	214.0	396.0	1018
5/11/2008	40.0	47.0	50	113		162.2	200.0	369.0	941
5/12/2008	37.9	45.0	48	98		140.1	177.0	341.0	856
5/13/2008	35.0	41.0	44	71		101.0	135.0	318.0	788
5/14/2008	31.8	38.0	40	71		100.7	135.0	303.0	744
5/15/2008	29.8	35.0	38	83		118.8	154.0	280.0	675
5/16/2008	33.5	40.0	43	83		119.4	154.0	263.0	624
5/17/2008	46.7	56.0	59	104		148.7	186.0	263.0	624
5/18/2008	43.6	52.0	55	96		137.2	174.0	260.0	616
5/19/2008	35.8	42.0	45	89		127.2	163.0	258.0	608
5/20/2008	32.3	38.0	40	88		126.1	162.0	247.0	575
5/21/2008	32.9	39.0	42	85		122.0	158.0	233.0	534
5/22/2008	39.2	46.0	49	83		118.7	154.0	224.0	507
5/23/2008	41.1	48.0	52	77		109.7	145.0	219.0	491
5/24/2008	38.8	46.0	49	73		104.1	139.0	209.0	462
5/25/2008	38.0	45.0	48	69		97.6	132.0	200.0	435

5/26/2008	39.1	46.0	49	67		96.3	130.0	188.0	400
5/27/2008	30.5	36.0	39	74		106.4	141.0	183.0	385
5/28/2008	27.5	32.0	34	70		100.4	134.0	186.0	395
5/29/2008	23.8	28.0	30	57		80.7	114.0	192.0	413
5/30/2008	21.7	26.0	28	51		72.8	106.0	190.0	407
5/31/2008	19.7	23.0	25	49		70.1	103.0	186.0	393
6/1/2008	19.7	23.0	25	48		69.5	102.0	175.0	362
6/2/2008	17.3	20.0	21	48		67.7	100.0	167.0	338
6/3/2008	15.2	17.0	19	54		76.8	110.0	157.0	308
6/4/2008	15.8	18.0	20	64		91.2	125.0	153.0	297
6/5/2008	17.8	21.0	23	66		94.0	128.0	158.0	310
6/6/2008	19.6	23.0	25	65		93.2	127.0	169.0	343
6/7/2008	20.5	23.0	25	56		79.5	113.0	173.0	355
6/8/2008	18.5	21.0	23	50		72.5	105.0	173.0	355
6/9/2008	16.2	18.0	20	46		65.7	98.0	168.0	341
6/10/2008	14.7	17.0	19	42		60.3	92.0	160.0	317
6/11/2008	13.8	16.0	18	38		55.2	87.0	150.0	287
6/12/2008	12.3	14.0	15	32		46.3	77.0	140.0	257
6/13/2008	11.0	13.0	14	21		30.3	60.0	127.0	218
6/14/2008	10.0	11.0	13	19		26.7	57.0	123.0	205
6/15/2008	14.5	16.0	18	48		68.9	102.0	121.0	201
6/16/2008	16.0	18.0	20	38		54.3	86.0	122.0	202
6/17/2008	24.3	28.0	30	64		91.0	125.0	132.0	232
6/18/2008	18.5	21.0	23	39		55.8	88.0	137.0	247
6/19/2008	15.8	18.0	20	32		45.2	76.0	136.0	244
6/20/2008	13.5	16.0	18	29		40.7	72.0	131.0	230
6/21/2008	12.3	14.0	15	29		40.9	72.0	125.0	211
6/22/2008	10.9	13.0	14	24		34.6	66.0	118.0	190
6/23/2008	33.6	40.0	43	73		104.2	139.0	129.0	223
6/24/2008	56.2	67.0	71	117		167.0	205.0	153.0	295
6/25/2008	64.9	78.0	82	134		191.2	231.0	183.0	385
6/26/2008	46.0	55.0	58	120		172.3	211.0	203.0	444
6/27/2008	32.8	39.0	42	148		211.8	253.0	210.0	467
6/28/2008	27.8	33.0	35	178		254.6	298.0	216.0	484
6/29/2008	34.2	40.0	43	164		234.7	277.0	221.0	497
6/30/2008	26.6	32.0	34	140		200.4	240.0	227.0	516
7/1/2008	21.8	26.0	28	78		112.3	147.0	217.0	486
7/2/2008	23.4	27.0	29	63		89.7	124.0	220.0	495
7/3/2008	20.9	24.0	26	57		82.0	115.0	234.0	538
7/4/2008	19.1	22.0	24	61		87.2	121.0	251.0	587
7/5/2008	18.7	22.0	24	49		70.3	103.0	237.0	547
7/6/2008	17.3	20.0	21	43		61.7	94.0	229.0	521
7/7/2008	15.1	17.0	19	55		78.9	112.0	217.0	487
7/8/2008	13.1	15.0	16	104		148.7	186.0	203.0	446
7/9/2008	11.2	13.0	14	104		149.0	186.0	187.0	397
7/10/2008	11.4	13.0	14	100		143.0	180.0	199.0	432
7/11/2008	14.0	16.0	18	38		53.8	86.0	209.0	464
7/12/2008	10.7	13.0	14	27		38.6	70.0	201.0	439
7/13/2008	8.2	9.3	10	24		34.3	64.0	187.0	396
7/14/2008	7.1	8.0	9	21		30.2	60.0	169.0	342
7/15/2008	6.5	7.3	8	19		26.8	57.0	153.0	296

7/16/2008	6.0	6.7	8	17		24.3	54.0	140.0	256
7/17/2008	5.2	5.8	7	15		22.2	52.0	127.0	219
7/18/2008	4.8	5.3	6	14		20.4	50.0	117.0	189
7/19/2008	3.9	4.3	5	14		19.7	50.0	110.0	167
7/20/2008	3.8	4.2	5	13		17.7	48.0	108.0	160
7/21/2008	7.2	8.1	9	61		87.5	121.0	131.0	230
7/22/2008	5.3	5.9	7	24		35.0	66.0	156.0	304
7/23/2008	10.6	13.0	14	55		78.6	112.0	168.0	340
7/24/2008	82.6	100.0	105	251		358.2	408.0	301.0	736
7/25/2008	93.2	112.0	117	370		528.0	588.0	393.0	1014
7/26/2008	73.1	88.0	92	336		480.0	538.0	423.0	1099
7/27/2008	55.3	66.0	69	302		431.0	485.0	463.0	1220
7/28/2008	55.2	66.0	69	270		386.0	437.0	483.0	1277
7/29/2008	46.1	55.0	58	201		286.6	332.0	466.0	1234
7/30/2008	36.3	42.0	45	127		180.8	220.0	450.0	1176
7/31/2008	29.4	34.0	37	111		158.4	196.0	419.0	1086
8/1/2008	25.3	29.0	32	115		164.0	202.0	381.0	975
8/2/2008	21.8	26.0	28	88		125.9	162.0	349.0	880
8/3/2008	23.2	27.0	29	90		127.8	164.0	338.0	846
8/4/2008	24.6	29.0	32	102		144.9	182.0	314.0	777
8/5/2008	19.9	23.0	25	108		154.2	192.0	297.0	726
8/6/2008	24.4	28.0	30	125		178.7	218.0	296.0	723
8/7/2008	37.4	44.0	47	125		178.7	218.0	292.0	710
8/8/2008	77.6	94.0	98	202		288.7	334.0	293.0	714
8/9/2008	129.1	157.0	163	233		332.6	381.0	316.0	781
8/10/2008	116.3	141.0	146	225		322.5	369.0	349.0	880
8/11/2008	89.6	109.0	113	230		329.5	377.0	409.0	1057
8/12/2008	68.9	83.0	87	217		309.7	357.0	453.0	1194
8/13/2008	60.3	72.0	76	194		277.0	322.0	470.0	1240
8/14/2008	54.4	64.0	68	176		251.9	295.0	460.0	1207
8/15/2008	50.9	61.0	64	144		205.0	246.0	440.0	1154
8/16/2008	54.8	66.0	69	105		149.6	187.0	436.0	1142
8/17/2008	51.9	62.0	66	89		126.5	163.0	429.0	1120
8/18/2008	45.5	53.0	57	96		137.0	174.0	409.0	1061
8/19/2008	38.3	45.0	48	132		188.7	229.0	381.0	975
8/20/2008	32.1	38.0	40	116		164.9	203.0	352.0	889
8/21/2008	27.4	32.0	34	93		133.5	169.0	323.0	803
8/22/2008	24.2	28.0	30	81		115.5	151.0	298.0	727
8/23/2008	21.7	26.0	28	54		77.0	110.0	273.0	654
8/24/2008	20.2	23.0	25	49		69.6	103.0	248.0	578
8/25/2008	19.2	22.0	24	50		70.7	104.0	224.0	508
8/26/2008	16.9	20.0	21	60		86.5	120.0	202.0	441
8/27/2008	15.4	17.0	19	42		59.9	92.0	182.0	383
8/28/2008	14.5	17.0	19	29		41.5	73.0	161.0	320
8/29/2008	13.2	15.0	16	24		35.3	66.0	145.0	272
8/30/2008	12.5	14.0	15	24		34.5	66.0	133.0	236
8/31/2008	11.5	13.0	14	22		32.1	62.0	126.0	216
9/1/2008	10.1	11.0	13	20		28.0	58.0	117.0	187
9/2/2008	9.2	10.0	12	18		25.2	55.0	112.0	174
9/3/2008	8.4	9.5	11	18		24.7	55.0	112.0	172
9/4/2008	7.7	8.7	10	15		21.7	52.0	108.0	160

9/5/2008	8.1	9.1	10	14		20.0	50.0	102.0	143
9/6/2008	18.9	22.0	24	48		68.0	100.0	113.0	175
9/7/2008	181.9	224.0	229	371		530.4	590.0	409.0	1056
9/8/2008	180.6	223.0	228	374		535.0	595.0	453.0	1190
9/9/2008	129.5	159.0	164	372		532.4	592.0	530.0	1419
9/10/2008	85.8	104.0	108	318		455.1	510.0	584.0	1578
9/11/2008	64.6	78.0	82	274		391.6	444.0	584.0	1578
9/12/2008	52.9	63.0	67	218		311.8	359.0	557.0	1500
9/13/2008	49.0	58.0	62	150		214.4	255.0	517.0	1377
9/14/2008	54.7	66.0	69	158		224.5	267.0	486.0	1290
9/15/2008	54.7	66.0	69	134		192.0	232.0	453.0	1191
9/16/2008	54.4	64.0	68	99		141.7	179.0	416.0	1079
9/17/2008	48.6	58.0	62	85		120.8	157.0	383.0	982
9/18/2008	42.1	50.0	53	59		83.7	117.0	347.0	875
9/19/2008	37.6	45.0	48	49		70.4	103.0	323.0	803
9/20/2008	33.2	39.0	42	44		62.7	95.0	286.0	692
9/21/2008	29.5	35.0	38	40		56.5	89.0	257.0	605
9/22/2008	26.9	32.0	34	36		50.7	82.0	234.0	538
9/23/2008	25.0	29.0	32	38		55.2	87.0	216.0	484
9/24/2008	22.8	27.0	29	64		90.7	125.0	202.0	441
9/25/2008	22.1	26.0	28	76		109.4	144.0	180.0	375
9/26/2008	45.5	53.0	57	186		265.5	310.0	197.0	428
9/27/2008	76.2	91.0	96	300		429.4	483.0	294.0	717
9/28/2008	117.6	144.0	149	377		537.7	598.0	403.0	1036
9/29/2008	112.1	136.0	141	374		533.8	594.0	466.0	1234
9/30/2008	88.4	106.0	111	318		454.7	510.0	503.0	1338

Date	1: Upstream	2: Into Res 2	3: Res 2 to Res 1	4: Res 3 to Res 1	5: Saxonville Dam	6: Rt 20	7 - 13: GMNWR 25 - 31	14: GMNWR 32
10/1/2006	0.17	0.02	0.03	0.54	0.32	0.42	0.06	0.23
10/2/2006	0.23	0.03	0.03	0.34	0.29	0.39	0.12	0.46
10/3/2006	0.66	0.11	0.06	0.00	0.23	0.36	0.14	0.57
10/4/2006	0.53	0.09	0.06	0.28	0.41	0.47	0.07	0.29
10/5/2006	0.42	0.06	0.06	1.19	0.73	0.74	0.00	0.00
10/6/2006	0.27	0.04	0.03	0.96	0.58	0.61	0.03	0.10
10/7/2006	0.20	0.02	0.03	0.23	0.21	0.33	0.18	0.71
10/8/2006	0.21	0.03	0.03	0.13	0.16	0.32	0.17	0.68
10/9/2006	0.20	0.02	0.03	0.14	0.16	0.32	0.15	0.59
10/10/2006	0.20	0.03	0.03	0.12	0.18	0.30	0.13	0.51
10/11/2006	0.18	0.02	0.03	0.14	0.18	0.30	0.12	0.50
10/12/2006	0.97	0.16	0.08	1.98	1.39	1.24	0.00	0.00
10/13/2006	1.12	0.21	0.08	0.20	0.71	0.70	0.39	1.56
10/14/2006	1.06	0.18	0.08	0.00	0.54	0.60	0.50	2.00
10/15/2006	0.68	0.11	0.06	0.17	0.43	0.51	0.51	2.04
10/16/2006	0.48	0.08	0.03	0.57	0.47	0.58	0.40	1.61
10/17/2006	0.45	0.06	0.06	1.59	0.92	0.86	0.15	0.59
10/18/2006	0.38	0.04	0.03	1.76	0.92	0.92	0.11	0.44
10/19/2006	0.39	0.06	0.06	1.36	0.83	0.79	0.15	0.60
10/20/2006	0.37	0.06	0.03	1.42	0.81	0.80	0.17	0.68
10/21/2006	0.62	0.12	0.06	0.45	0.53	0.60	0.32	1.29
10/22/2006	0.64	0.12	0.06	0.08	0.41	0.47	0.36	1.44
10/23/2006	0.58	0.07	0.06	0.42	0.48	0.53	0.30	1.20
10/24/2006	0.53	0.10	0.06	1.19	0.83	0.78	0.13	0.53
10/25/2006	0.51	0.09	0.06	1.19	0.80	0.78	0.11	0.44
10/26/2006	0.65	0.11	0.06	1.02	0.79	0.79	0.08	0.31
10/27/2006	0.94	0.16	0.08	0.79	0.84	0.83	0.05	0.18
10/28/2006	1.69	0.35	0.11	2.69	2.07	1.75	0.00	0.00
10/29/2006	3.12	0.67	0.14	1.36	2.27	1.92	0.00	0.00
10/30/2006	2.68	0.58	0.14	1.05	1.91	1.63	0.11	0.44
10/31/2006	2.15	0.43	0.14	1.61	1.87	1.61	0.19	0.77
11/1/2006	1.56	0.31	0.08	1.98	1.69	1.49	0.27	1.10
11/2/2006	1.26	0.22	0.08	1.50	1.29	1.20	0.39	1.57
11/3/2006	1.09	0.21	0.08	0.25	0.71	0.70	0.59	2.37
11/4/2006	0.93	0.17	0.08	0.17	0.58	0.61	0.59	2.34
11/5/2006	0.81	0.15	0.08	0.17	0.52	0.56	0.54	2.17
11/6/2006	0.73	0.12	0.08	0.20	0.49	0.53	0.48	1.90
11/7/2006	0.69	0.10	0.06	0.23	0.49	0.53	0.42	1.66
11/8/2006	0.80	0.13	0.06	1.67	1.14	1.04	0.12	0.50
11/9/2006	1.87	0.36	0.11	3.77	2.60	2.18	0.00	0.00
11/10/2006	2.03	0.41	0.14	1.81	1.87	1.61	0.15	0.60
11/11/2006	1.94	0.41	0.11	0.00	1.05	0.99	0.57	2.27
11/12/2006	1.49	0.30	0.11	0.51	1.04	0.97	0.59	2.34
11/13/2006	1.60	0.30	0.11	0.59	1.14	1.04	0.55	2.22
11/14/2006	2.50	0.51	0.14	3.88	3.02	2.48	0.00	0.00
11/15/2006	2.72	0.56	0.14	3.40	2.92	2.40	0.04	0.15
11/16/2006	2.50	0.50	0.14	3.14	2.68	2.24	0.20	0.80
11/17/2006	3.66	0.79	0.17	4.95	4.10	3.32	0.00	0.00

11/18/2006	4.22	0.96	0.14	3.96	3.99	3.23	0.00	0.00
11/19/2006	3.50	0.77	0.14	3.94	3.57	2.91	0.13	0.53
11/20/2006	2.59	0.53	0.14	4.11	3.16	2.61	0.33	1.30
11/21/2006	2.10	0.42	0.11	3.57	2.67	2.20	0.49	1.95
11/22/2006	1.86	0.37	0.11	4.11	2.75	2.29	0.39	1.55
11/23/2006	1.76	0.33	0.11	5.21	3.17	2.61	0.18	0.74
11/24/2006	4.49	1.01	0.14	3.60	3.97	3.19	0.05	0.18
11/25/2006	4.93	1.13	0.14	3.17	4.02	3.26	0.10	0.40
11/26/2006	4.12	0.95	0.14	3.40	3.72	2.99	0.31	1.25
11/27/2006	3.29	0.70	0.14	3.51	3.28	2.69	0.49	1.97
11/28/2006	2.89	0.63	0.14	3.85	3.24	2.62	0.45	1.80
11/29/2006	2.67	0.56	0.11	2.01	2.30	1.92	0.75	3.00
11/30/2006	2.57	0.54	0.14	0.93	1.78	1.56	0.87	3.50
12/1/2006	2.52	0.51	0.14	1.02	1.82	1.55	0.78	3.13
12/2/2006	2.95	0.61	0.14	1.22	2.13	1.81	0.61	2.42
12/3/2006	3.07	0.64	0.14	0.45	1.83	1.60	0.67	2.70
12/4/2006	2.85	0.60	0.14	0.96	1.97	1.66	0.58	2.33
12/5/2006	2.51	0.52	0.14	2.27	2.33	1.94	0.36	1.45
12/6/2006	2.38	0.48	0.14	2.15	2.21	1.86	0.34	1.37
12/7/2006	2.30	0.48	0.11	2.29	2.24	1.87	0.28	1.11
12/8/2006	2.16	0.42	0.14	2.21	2.12	1.81	0.26	1.04
12/9/2006	2.03	0.41	0.14	1.50	1.75	1.54	0.36	1.44
12/10/2006	2.05	0.44	0.11	1.39	1.71	1.46	0.33	1.33
12/11/2006	1.96	0.39	0.11	0.93	1.43	1.32	0.39	1.54
12/12/2006	1.87	0.37	0.11	0.03	1.01	0.97	0.52	2.07
12/13/2006	1.83	0.38	0.11	0.00	1.00	0.93	0.49	1.95
12/14/2006	1.92	0.41	0.11	0.00	1.01	0.98	0.44	1.76
12/15/2006	1.54	0.28	0.11	0.28	0.95	0.89	0.43	1.73
12/16/2006	1.39	0.25	0.11	0.28	0.87	0.86	0.42	1.69
12/17/2006	1.33	0.26	0.08	0.28	0.81	0.83	0.40	1.62
12/18/2006	1.30	0.26	0.08	0.28	0.81	0.83	0.37	1.46
12/19/2006	1.27	0.23	0.11	0.25	0.79	0.80	0.33	1.33
12/20/2006	1.25	0.22	0.08	0.25	0.77	0.76	0.31	1.23
12/21/2006	1.26	0.22	0.08	0.25	0.77	0.76	0.28	1.12
12/22/2006	1.22	0.23	0.08	0.59	0.89	0.89	0.19	0.76
12/23/2006	1.71	0.35	0.11	2.15	1.83	1.60	0.00	0.00
12/24/2006	2.21	0.45	0.11	1.42	1.79	1.55	0.01	0.03
12/25/2006	2.15	0.43	0.14	1.13	1.66	1.45	0.13	0.52
12/26/2006	2.26	0.46	0.14	2.27	2.19	1.86	0.01	0.05
12/27/2006	2.25	0.46	0.14	2.55	2.33	1.95	0.00	0.00
12/28/2006	2.10	0.42	0.11	2.49	2.19	1.86	0.08	0.33
12/29/2006	1.80	0.38	0.11	1.64	1.69	1.48	0.28	1.13
12/30/2006	1.60	0.32	0.11	0.25	0.99	0.93	0.55	2.20
12/31/2006	1.50	0.29	0.11	0.25	0.91	0.88	0.53	2.13
1/1/2007	1.83	0.38	0.11	0.82	1.35	1.22	0.37	1.49
1/2/2007	2.80	0.60	0.14	1.05	1.95	1.67	0.19	0.77
1/3/2007	2.85	0.60	0.14	2.77	2.71	2.27	0.00	0.00
1/4/2007	2.41	0.50	0.11	3.88	2.97	2.43	0.00	0.00
1/5/2007	2.05	0.39	0.14	2.35	2.11	1.82	0.23	0.94
1/6/2007	1.93	0.39	0.11	0.37	1.18	1.12	0.62	2.47
1/7/2007	1.80	0.33	0.11	0.31	1.10	1.02	0.62	2.48
1/8/2007	2.07	0.42	0.11	1.39	1.70	1.47	0.41	1.63

1/9/2007	2.74	0.57	0.14	1.78	2.24	1.90	0.22	0.89
1/10/2007	2.68	0.57	0.14	2.18	2.38	2.01	0.18	0.70
1/11/2007	2.19	0.44	0.11	2.69	2.32	1.95	0.21	0.85
1/12/2007	1.98	0.40	0.11	2.38	2.10	1.78	0.30	1.19
1/13/2007	1.91	0.36	0.11	0.40	1.19	1.07	0.63	2.50
1/14/2007	1.84	0.37	0.11	0.34	1.13	1.05	0.60	2.41
1/15/2007	2.27	0.45	0.14	0.93	1.65	1.40	0.43	1.72
1/16/2007	2.90	0.61	0.14	1.93	2.39	2.00	0.15	0.60
1/17/2007	2.71	0.58	0.14	4.33	3.34	2.72	0.00	0.00
1/18/2007	2.14	0.43	0.14	3.62	2.72	2.27	0.03	0.11
1/19/2007	2.01	0.40	0.11	0.68	1.39	4.98	0.20	0.82
1/20/2007	2.01	0.40	0.11	0.08	1.10	4.82	0.28	1.11
1/21/2007	1.68	0.30	0.11	0.34	1.06	4.01	0.29	1.14
1/22/2007	1.69	0.35	0.11	0.62	1.19	2.83	0.30	1.19
1/23/2007	1.60	0.32	0.11	1.36	1.46	1.31	0.31	1.26
1/24/2007	1.55	0.32	0.08	2.38	1.83	1.59	0.12	0.46
1/25/2007	1.50	0.28	0.11	2.86	2.05	1.72	0.01	0.02
1/26/2007	1.34	0.24	0.08	2.12	1.63	1.42	0.12	0.48
1/27/2007	1.22	0.22	0.08	0.54	0.86	0.86	0.37	1.48
1/28/2007	1.19	0.23	0.08	0.51	0.85	0.85	0.34	1.35
1/29/2007	1.24	0.23	0.08	0.40	0.86	0.81	0.31	1.22
1/30/2007	1.19	0.23	0.08	0.40	0.83	0.78	0.27	1.09
1/31/2007	1.14	0.19	0.08	0.48	0.83	0.79	0.24	0.95
2/1/2007	1.10	0.20	0.08	0.42	0.79	0.76	0.21	0.84
2/2/2007	1.09	0.21	0.08	0.42	0.79	0.77	0.18	0.71
2/3/2007	0.97	0.17	0.08	0.65	0.82	0.79	0.16	0.62
2/4/2007	0.92	0.16	0.06	0.62	0.74	0.77	0.16	0.63
2/5/2007	0.88	0.14	0.08	0.54	0.71	0.70	0.15	0.61
2/6/2007	0.79	0.14	0.06	1.36	0.98	0.94	0.01	0.03
2/7/2007	0.72	0.10	0.08	3.00	1.66	1.48	0.00	0.00
2/8/2007	0.67	0.12	0.06	2.66	1.49	1.34	0.00	0.00
2/9/2007	0.64	0.10	0.06	1.76	1.06	1.03	0.02	0.07
2/10/2007	0.61	0.12	0.06	0.62	0.62	0.66	0.20	0.78
2/11/2007	0.60	0.07	0.06	0.59	0.57	0.62	0.17	0.69
2/12/2007	0.60	0.08	0.06	0.59	0.56	0.63	0.14	0.55
2/13/2007	0.60	0.08	0.06	0.57	0.56	0.63	0.12	0.49
2/14/2007	1.16	0.20	0.11	0.28	0.74	0.11	0.08	0.33
2/15/2007	2.19	0.45	0.11	0.00	0.95	0.92	0.00	0.00
2/16/2007	1.55	0.31	0.08	1.50	1.51	1.32	0.00	0.00
2/17/2007	1.04	0.21	0.08	3.65	2.14	1.82	0.00	0.00
2/18/2007	0.86	0.16	0.08	3.43	1.93	1.66	0.00	0.00
2/19/2007	0.84	0.15	0.08	2.60	1.57	1.38	0.00	0.00
2/20/2007	0.75	0.16	0.06	2.18	1.36	1.21	0.00	0.00
2/21/2007	0.65	0.12	0.06	1.78	1.11	1.02	0.00	0.00
2/22/2007	0.65	0.11	0.06	1.39	0.93	0.91	0.00	0.01
2/23/2007	0.67	0.13	0.06	1.10	0.86	0.81	0.04	0.16
2/24/2007	0.68	0.11	0.06	1.10	0.82	0.82	0.04	0.16
2/25/2007	0.67	0.12	0.06	1.90	1.18	1.09	0.00	0.00
2/26/2007	0.67	0.12	0.06	2.49	1.42	1.27	0.00	0.00
2/27/2007	0.66	0.11	0.06	1.59	1.01	0.97	0.00	0.00
2/28/2007	0.66	0.10	0.06	1.02	0.78	0.80	0.07	0.28
3/1/2007	0.68	0.11	0.06	1.78	1.12	0.86	0.00	0.00

3/2/2007	2.07	0.42	0.11	5.86	3.63	2.94	0.00	0.00
3/3/2007	4.30	0.97	0.17	4.90	4.42	3.56	0.00	0.00
3/4/2007	4.72	1.08	0.14	4.22	4.36	3.51	0.00	0.00
3/5/2007	3.24	0.72	0.14	4.67	3.76	3.06	0.00	0.00
3/6/2007	2.46	0.51	0.14	3.94	3.03	2.49	0.22	0.89
3/7/2007	1.90	0.37	0.11	3.20	2.42	2.00	0.41	1.65
3/8/2007	1.55	0.32	0.08	2.01	1.71	1.46	0.61	2.43
3/9/2007	1.37	0.24	0.08	0.65	1.03	0.95	0.78	3.14
3/10/2007	1.27	0.23	0.11	0.68	0.98	0.95	0.68	2.72
3/11/2007	2.05	0.39	0.14	1.10	1.59	1.38	0.46	1.85
3/12/2007	2.88	0.63	0.14	1.16	2.08	1.74	0.29	1.14
3/13/2007	2.90	0.62	0.14	2.80	2.76	2.30	0.03	0.12
3/14/2007	3.14	0.68	0.14	3.34	3.14	2.58	0.00	0.00
3/15/2007	3.52	0.75	0.14	4.53	3.83	3.11	0.00	0.00
3/16/2007	3.25	0.72	0.14	4.78	3.79	3.09	0.00	0.00
3/17/2007	2.38	0.48	0.14	6.80	4.18	3.41	0.00	0.00
3/18/2007	2.20	0.46	0.11	4.98	3.30	2.73	0.10	0.41
3/19/2007	2.36	0.47	0.14	1.56	1.95	1.67	0.64	2.57
3/20/2007	2.41	0.51	0.11	1.47	1.92	1.65	0.59	2.38
3/21/2007	2.52	0.51	0.14	1.22	1.89	1.62	0.54	2.17
3/22/2007	2.48	0.52	0.14	2.01	2.22	1.86	0.40	1.60
3/23/2007	4.13	0.94	0.14	3.28	3.63	2.97	0.00	0.00
3/24/2007	4.77	1.09	0.14	3.82	4.21	3.40	0.00	0.00
3/25/2007	5.61	1.33	0.11	3.82	4.66	3.75	0.00	0.00
3/26/2007	5.89	1.39	0.14	4.05	4.91	3.93	0.00	0.00
3/27/2007	5.89	1.38	0.14	5.21	5.41	4.33	0.00	0.00
3/28/2007	6.12	1.44	0.14	4.93	5.40	4.34	0.00	0.00
3/29/2007	5.46	1.28	0.14	5.04	5.12	4.11	0.00	0.00
3/30/2007	4.59	1.05	0.14	4.30	4.33	3.49	0.30	1.21
3/31/2007	4.02	0.91	0.14	1.56	2.84	2.34	0.88	3.51
4/1/2007	3.61	0.80	0.14	1.19	2.47	2.06	0.94	3.76
4/2/2007	3.90	0.88	0.14	2.43	3.18	2.60	0.55	2.21
4/3/2007	4.16	0.94	0.14	4.45	4.17	3.36	0.05	0.22
4/4/2007	3.92	0.89	0.14	5.41	4.44	3.57	0.00	0.00
4/5/2007	5.95	1.41	0.14	6.06	5.81	4.61	0.00	0.00
4/6/2007	6.70	1.62	0.14	4.47	5.55	4.42	0.00	0.00
4/7/2007	5.60	1.34	0.11	4.39	4.91	3.92	0.15	0.59
4/8/2007	4.45	1.02	0.14	4.67	4.38	3.55	0.37	1.46
4/9/2007	3.77	0.81	0.17	4.25	3.86	3.14	0.52	2.06
4/10/2007	3.37	0.73	0.14	3.60	3.36	2.76	0.61	2.42
4/11/2007	3.11	0.69	0.14	2.43	2.75	2.26	0.75	3.00
4/12/2007	2.97	0.62	0.14	2.58	2.73	2.25	0.67	2.67
4/13/2007	4.78	1.10	0.14	3.51	4.07	3.31	0.14	0.55
4/14/2007	5.32	1.24	0.14	3.31	4.26	3.46	0.07	0.27
4/15/2007	4.60	1.06	0.14	5.12	4.68	3.75	0.02	0.08
4/16/2007	13.10	3.49	0.00	5.10	9.30	7.32	0.00	0.00
4/17/2007	17.45	4.80	0.00	2.80	10.69	8.13	0.00	0.00
4/18/2007	15.12	4.07	0.00	5.92	10.71	8.49	0.00	0.00
4/19/2007	11.92	3.11	0.00	7.59	9.77	7.55	0.06	0.23
4/20/2007	9.38	2.37	0.06	8.81	8.78	7.13	0.45	1.81
4/21/2007	6.98	1.68	0.11	9.99	8.03	6.33	0.68	2.72
4/22/2007	5.90	1.38	0.14	10.14	7.54	6.05	0.71	2.83

4/23/2007	5.13	1.19	0.14	10.02	7.07	5.61	0.68	2.72
4/24/2007	4.57	1.04	0.14	9.68	6.58	5.25	0.61	2.46
4/25/2007	4.12	0.92	0.14	9.31	6.24	4.91	0.55	2.20
4/26/2007	4.05	0.90	0.14	7.62	5.44	4.32	0.67	2.67
4/27/2007	4.48	1.01	0.14	6.54	5.20	4.17	0.62	2.48
4/28/2007	5.41	1.27	0.14	6.99	5.92	4.70	0.21	0.83
4/29/2007	5.26	1.23	0.14	6.85	5.76	4.60	0.15	0.61
4/30/2007	4.64	1.08	0.14	6.82	5.43	4.34	0.21	0.85
5/1/2007	4.01	0.92	0.14	6.71	5.04	4.05	0.26	1.03
5/2/2007	3.66	0.79	0.17	6.51	4.80	3.81	0.25	0.99
5/3/2007	3.33	0.75	0.14	5.83	4.29	3.50	0.32	1.28
5/4/2007	2.94	0.63	0.14	5.61	3.98	3.24	0.33	1.30
5/5/2007	2.70	0.56	0.14	5.07	3.64	2.93	0.34	1.36
5/6/2007	2.53	0.50	0.14	4.95	3.49	2.82	0.26	1.05
5/7/2007	2.19	0.47	0.11	4.87	3.26	2.69	0.23	0.94
5/8/2007	1.81	0.37	0.11	4.67	2.97	2.47	0.25	1.01
5/9/2007	1.60	0.32	0.11	4.28	2.68	2.25	0.27	1.06
5/10/2007	1.45	0.28	0.08	4.11	2.54	2.13	0.23	0.92
5/11/2007	1.37	0.24	0.08	4.53	2.66	2.21	0.16	0.62
5/12/2007	1.47	0.28	0.11	4.16	2.58	2.15	0.18	0.70
5/13/2007	1.29	0.21	0.11	4.11	2.44	2.04	0.18	0.70
5/14/2007	1.15	0.18	0.08	4.16	2.37	2.02	0.14	0.57
5/15/2007	1.09	0.21	0.08	3.99	2.28	1.97	0.11	0.44
5/16/2007	1.09	0.19	0.08	5.35	2.89	2.38	0.00	0.00
5/17/2007	4.39	0.99	0.14	5.44	4.69	3.77	0.00	0.00
5/18/2007	4.98	1.16	0.14	7.30	5.81	4.64	0.00	0.00
5/19/2007	7.14	1.72	0.14	6.74	6.73	5.36	0.00	0.00
5/20/2007	7.01	1.71	0.11	7.13	6.84	5.40	0.00	0.00
5/21/2007	6.13	1.48	0.11	7.87	6.70	5.28	0.00	0.00
5/22/2007	4.25	0.96	0.14	8.27	5.83	4.65	0.10	0.42
5/23/2007	3.41	0.75	0.14	6.17	4.49	3.64	0.63	2.53
5/24/2007	2.78	0.59	0.11	3.48	2.98	2.45	1.15	4.60
5/25/2007	2.36	0.47	0.14	5.32	3.56	2.92	0.73	2.92
5/26/2007	2.24	0.45	0.14	6.48	3.99	3.23	0.37	1.48
5/27/2007	1.78	0.34	0.11	6.51	3.74	3.05	0.28	1.11
5/28/2007	1.49	0.30	0.11	6.40	3.55	2.88	0.21	0.85
5/29/2007	1.36	0.25	0.08	6.20	3.39	2.78	0.13	0.52
5/30/2007	1.19	0.22	0.08	6.23	3.30	2.73	0.05	0.19
5/31/2007	1.07	0.20	0.08	4.73	2.59	2.19	0.23	0.94
6/1/2007	1.08	0.19	0.08	2.43	1.61	1.41	0.55	2.19
6/2/2007	1.22	0.22	0.08	2.15	1.60	1.37	0.48	1.93
6/3/2007	1.11	0.20	0.08	2.07	1.46	1.31	0.42	1.69
6/4/2007	1.65	0.31	0.11	3.51	2.42	2.00	0.08	0.34
6/5/2007	3.17	0.68	0.14	2.75	2.88	2.39	0.03	0.11
6/6/2007	2.89	0.62	0.14	3.20	2.95	2.43	0.07	0.26
6/7/2007	2.13	0.41	0.11	3.23	2.51	2.13	0.25	0.99
6/8/2007	1.70	0.34	0.11	2.80	2.13	1.81	0.35	1.40
6/9/2007	1.54	0.27	0.11	3.40	2.26	1.93	0.23	0.93
6/10/2007	2.74	0.57	0.14	3.57	3.02	2.48	0.00	0.00
6/11/2007	2.87	0.58	0.14	5.32	3.81	3.12	0.00	0.00
6/12/2007	2.20	0.46	0.11	5.66	3.60	2.94	0.00	0.00
6/13/2007	1.68	0.30	0.11	5.01	3.06	2.52	0.00	0.00

6/14/2007	1.69	0.35	0.11	4.67	2.91	2.41	0.00	0.00
6/15/2007	1.37	0.25	0.08	5.61	3.13	2.59	0.00	0.00
6/16/2007	1.05	0.19	0.08	4.30	2.41	2.04	0.01	0.02
6/17/2007	0.88	0.14	0.08	2.89	1.69	1.48	0.23	0.94
6/18/2007	0.77	0.14	0.06	2.27	1.39	1.24	0.29	1.14
6/19/2007	0.71	0.11	0.08	3.34	1.82	1.55	0.03	0.12
6/20/2007	0.73	0.12	0.08	1.02	0.86	0.81	0.35	1.42
6/21/2007	0.69	0.10	0.06	0.82	0.71	0.73	0.34	1.37
6/22/2007	0.80	0.14	0.06	1.59	1.11	1.02	0.12	0.49
6/23/2007	0.72	0.10	0.08	3.45	1.87	1.61	0.00	0.00
6/24/2007	0.65	0.11	0.06	3.06	1.66	1.46	0.00	0.00
6/25/2007	0.59	0.09	0.06	3.06	1.65	1.40	0.00	0.00
6/26/2007	0.52	0.08	0.06	3.09	1.58	1.42	0.00	0.00
6/27/2007	0.70	0.12	0.08	2.07	1.29	1.15	0.00	0.00
6/28/2007	0.57	0.08	0.06	0.25	0.41	0.52	0.24	0.95
6/29/2007	0.42	0.07	0.06	0.62	0.49	0.56	0.16	0.65
6/30/2007	0.34	0.06	0.03	2.52	1.26	1.17	0.00	0.00
7/1/2007	0.30	0.07	0.03	2.55	1.24	1.14	0.00	0.00
7/2/2007	0.27	0.04	0.03	2.55	1.26	1.12	0.00	0.00
7/3/2007	0.24	0.03	0.04	2.52	1.22	1.10	0.00	0.00
7/4/2007	0.22	0.03	0.03	2.32	1.13	1.05	0.00	0.00
7/5/2007	0.22	0.03	0.03	2.49	1.20	1.07	0.00	0.00
7/6/2007	0.24	0.03	0.04	2.49	1.18	1.11	0.00	0.00
7/7/2007	0.23	0.03	0.03	2.32	1.14	1.04	0.00	0.00
7/8/2007	0.22	0.03	0.03	2.61	1.21	1.14	0.00	0.00
7/9/2007	0.42	0.06	0.06	4.64	2.24	1.86	0.00	0.00
7/10/2007	0.53	0.09	0.06	6.00	2.85	2.39	0.00	0.00
7/11/2007	0.75	0.15	0.06	4.56	2.35	1.98	0.00	0.00
7/12/2007	0.57	0.08	0.06	1.84	1.10	1.02	0.00	0.00
7/13/2007	0.38	0.05	0.03	0.31	0.35	0.42	0.30	1.20
7/14/2007	0.29	0.02	0.06	0.14	0.20	0.34	0.30	1.20
7/15/2007	0.26	0.02	0.03	0.11	0.18	0.33	0.26	1.03
7/16/2007	0.25	0.03	0.03	0.06	0.17	0.31	0.22	0.88
7/17/2007	0.26	0.05	0.03	0.03	0.17	0.31	0.16	0.63
7/18/2007	0.23	0.03	0.03	0.93	0.51	0.56	0.00	0.00
7/19/2007	0.21	0.03	0.03	3.64	1.67	1.48	0.00	0.00
7/20/2007	0.22	0.03	0.03	3.26	1.50	1.33	0.00	0.00
7/21/2007	0.21	0.03	0.03	3.02	1.40	1.24	0.00	0.00
7/22/2007	0.20	0.03	0.03	3.03	1.38	1.25	0.00	0.00
7/23/2007	0.20	0.02	0.03	3.04	1.40	1.23	0.00	0.00
7/24/2007	0.20	0.03	0.03	2.94	1.40	1.24	0.00	0.00
7/25/2007	0.20	0.03	0.03	1.51	0.77	0.76	0.00	0.00
7/26/2007	0.19	0.02	0.03	0.27	0.20	0.34	0.16	0.63
7/27/2007	0.17	0.02	0.02	0.13	0.13	0.29	0.14	0.57
7/28/2007	0.16	0.02	0.02	0.22	0.21	0.30	0.08	0.34
7/29/2007	0.15	0.02	0.02	0.32	0.21	0.35	0.02	0.08
7/30/2007	0.17	0.02	0.02	0.41	0.25	0.37	0.03	0.10
7/31/2007	0.24	0.03	0.04	0.31	0.25	0.38	0.06	0.23
8/1/2007	0.23	0.03	0.03	0.17	0.19	0.35	0.08	0.34
8/2/2007	0.21	0.03	0.03	0.10	0.18	0.30	0.09	0.36
8/3/2007	0.18	0.02	0.03	0.11	0.15	0.28	0.08	0.32
8/4/2007	0.17	0.02	0.03	0.06	0.12	0.28	0.07	0.27

8/5/2007	0.16	0.02	0.02	0.01	0.11	0.24	0.06	0.24
8/6/2007	0.15	0.02	0.02	0.09	0.13	0.29	0.04	0.17
8/7/2007	0.15	0.02	0.02	0.12	0.15	0.27	0.04	0.16
8/8/2007	0.15	0.02	0.02	0.18	0.18	0.30	0.05	0.18
8/9/2007	0.14	0.02	0.02	0.10	0.15	0.27	0.06	0.24
8/10/2007	0.14	0.02	0.02	0.10	0.11	0.29	0.05	0.22
8/11/2007	0.14	0.02	0.02	0.11	0.13	0.29	0.05	0.18
8/12/2007	0.14	0.02	0.02	0.08	0.11	0.26	0.05	0.20
8/13/2007	0.14	0.02	0.02	0.67	0.36	0.46	0.00	0.00
8/14/2007	0.14	0.02	0.02	2.63	1.20	1.10	0.00	0.00
8/15/2007	0.13	0.02	0.02	2.47	1.14	1.04	0.00	0.00
8/16/2007	0.13	0.01	0.02	2.47	1.14	1.04	0.00	0.00
8/17/2007	0.13	0.02	0.02	1.90	0.88	0.85	0.00	0.00
8/18/2007	0.13	0.01	0.02	0.26	0.21	0.30	0.09	0.36
8/19/2007	0.13	0.02	0.02	0.03	0.08	0.24	0.10	0.41
8/20/2007	0.14	0.02	0.02	0.00	0.06	0.23	0.07	0.29
8/21/2007	0.14	0.01	0.02	0.00	0.07	0.23	0.05	0.20
8/22/2007	0.13	0.01	0.02	0.00	0.07	0.22	0.04	0.16
8/23/2007	0.13	0.01	0.02	0.00	0.07	0.23	0.03	0.14
8/24/2007	0.12	0.01	0.02	0.01	0.07	0.24	0.03	0.12
8/25/2007	0.12	0.01	0.02	0.02	0.07	0.24	0.03	0.10
8/26/2007	0.11	0.01	0.02	0.02	0.07	0.23	0.02	0.09
8/27/2007	0.10	0.01	0.01	0.01	0.06	0.22	0.02	0.08
8/28/2007	0.10	0.01	0.01	0.00	0.05	0.21	0.02	0.09
8/29/2007	0.10	0.01	0.02	0.00	0.05	0.22	0.02	0.08
8/30/2007	0.09	0.01	0.02	0.00	0.05	0.23	0.02	0.09
8/31/2007	0.09	0.01	0.02	0.00	0.05	0.21	0.02	0.09
9/1/2007	0.08	0.01	0.01	0.00	0.05	0.22	0.02	0.08
9/2/2007	0.07	0.01	0.01	0.01	0.04	0.23	0.02	0.08
9/3/2007	0.06	0.01	0.01	0.02	0.04	0.23	0.02	0.08
9/4/2007	0.06	0.01	0.01	0.03	0.04	0.20	0.01	0.06
9/5/2007	0.05	0.00	0.01	0.03	0.04	0.21	0.01	0.05
9/6/2007	0.05	0.00	0.01	0.03	0.04	0.21	0.01	0.05
9/7/2007	0.05	0.00	0.01	0.04	0.04	0.21	0.01	0.05
9/8/2007	0.04	0.00	0.01	0.04	0.04	0.21	0.01	0.03
9/9/2007	0.05	0.00	0.01	0.03	0.04	0.21	0.03	0.14
9/10/2007	0.08	0.01	0.01	0.00	0.04	0.23	0.01	0.06
9/11/2007	0.16	0.02	0.02	0.79	0.42	0.51	0.00	0.00
9/12/2007	0.17	0.02	0.02	0.50	0.30	0.44	0.02	0.09
9/13/2007	0.13	0.01	0.02	0.58	0.31	0.43	0.02	0.08
9/14/2007	0.13	0.01	0.02	1.79	0.86	0.81	0.00	0.00
9/15/2007	0.14	0.01	0.02	0.45	0.26	0.36	0.05	0.18
9/16/2007	0.12	0.01	0.02	0.13	0.13	0.29	0.09	0.37
9/17/2007	0.12	0.01	0.02	0.30	0.19	0.35	0.03	0.12
9/18/2007	0.12	0.01	0.02	1.57	0.74	0.73	0.00	0.00
9/19/2007	0.12	0.01	0.02	1.33	0.66	0.67	0.00	0.00
9/20/2007	0.11	0.01	0.02	0.23	0.15	0.28	0.06	0.25
9/21/2007	0.10	0.01	0.01	0.07	0.09	0.25	0.07	0.27
9/22/2007	0.09	0.01	0.02	0.06	0.08	0.23	0.06	0.23
9/23/2007	0.09	0.01	0.02	0.05	0.07	0.23	0.04	0.16
9/24/2007	0.09	0.01	0.01	0.04	0.07	0.24	0.03	0.14
9/25/2007	0.08	0.01	0.01	0.03	0.06	0.23	0.03	0.14

9/26/2007	0.08	0.01	0.01	0.03	0.06	0.24	0.03	0.12
9/27/2007	0.08	0.01	0.01	0.03	0.05	0.21	0.03	0.14
9/28/2007	0.08	0.01	0.01	0.05	0.07	0.24	0.02	0.09
9/29/2007	0.07	0.01	0.01	0.05	0.06	0.23	0.02	0.09
9/30/2007	0.06	0.00	0.01	0.04	0.05	0.23	0.02	0.09
10/1/2007	0.07	0.00	0.01	0.03	0.05	0.82	0.09	0.36
10/2/2007	0.06	0.01	0.01	0.05	0.05	0.83	0.09	0.36
10/3/2007	0.05	0.00	0.01	0.05	0.05	0.82	0.09	0.36
10/4/2007	0.05	0.00	0.01	0.06	0.05	0.82	0.09	0.36
10/5/2007	0.04	0.00	0.01	0.07	0.05	0.82	0.09	0.36
10/6/2007	0.04	0.00	0.01	0.07	0.05	0.81	0.09	0.36
10/7/2007	0.04	0.00	0.01	0.08	0.05	0.81	0.09	0.36
10/8/2007	0.05	0.01	0.01	0.24	0.13	0.83	0.07	0.29
10/9/2007	0.05	0.00	0.01	0.15	0.09	0.82	0.08	0.34
10/10/2007	0.04	0.00	0.01	0.12	0.07	0.83	0.09	0.36
10/11/2007	0.04	0.00	0.01	0.12	0.08	0.82	0.09	0.36
10/12/2007	0.05	0.01	0.01	0.30	0.14	0.85	0.07	0.29
10/13/2007	0.05	0.00	0.01	0.19	0.12	0.81	0.10	0.42
10/14/2007	0.05	0.00	0.01	0.09	0.07	0.81	0.12	0.50
10/15/2007	0.04	0.00	0.01	0.08	0.06	0.81	0.12	0.50
10/16/2007	0.04	0.00	0.01	0.07	0.05	0.82	0.12	0.48
10/17/2007	0.04	0.00	0.01	0.07	0.05	0.82	0.11	0.45
10/18/2007	0.04	0.00	0.01	0.07	0.05	0.82	0.11	0.44
10/19/2007	0.03	0.00	0.01	0.24	0.11	0.83	0.09	0.37
10/20/2007	0.18	0.02	0.03	0.87	0.48	0.91	0.03	0.12
10/21/2007	0.18	0.02	0.02	0.17	0.17	0.85	0.14	0.54
10/22/2007	0.17	0.02	0.03	0.06	0.12	0.82	0.17	0.67
10/23/2007	0.17	0.02	0.03	0.06	0.13	0.81	0.16	0.65
10/24/2007	0.14	0.02	0.02	0.10	0.15	0.81	0.15	0.59
10/25/2007	0.14	0.01	0.02	0.09	0.11	0.82	0.14	0.58
10/26/2007	0.13	0.01	0.02	0.07	0.10	0.83	0.12	0.49
10/27/2007	0.17	0.02	0.02	0.30	0.21	0.84	0.08	0.32
10/28/2007	0.24	0.03	0.04	0.14	0.19	0.86	0.11	0.43
10/29/2007	0.24	0.03	0.04	0.00	0.15	0.81	0.13	0.53
10/30/2007	0.25	0.03	0.03	0.00	0.13	0.81	0.13	0.53
10/31/2007	0.26	0.05	0.03	0.00	0.13	0.83	0.12	0.49
11/1/2007	0.19	0.02	0.03	0.08	0.15	0.81	0.12	0.48
11/2/2007	0.17	0.02	0.03	1.39	0.68	0.94	0.00	0.00
11/3/2007	0.19	0.02	0.03	5.42	2.43	1.28	0.00	0.00
11/4/2007	0.51	0.09	0.06	3.77	1.90	1.18	0.00	0.00
11/5/2007	0.40	0.05	0.06	0.96	0.66	0.93	0.15	0.61
11/6/2007	0.47	0.04	0.06	1.25	0.77	0.96	0.10	0.39
11/7/2007	0.63	0.11	0.06	0.62	0.63	0.93	0.14	0.57
11/8/2007	0.59	0.09	0.06	0.00	0.31	0.87	0.24	0.95
11/9/2007	0.50	0.10	0.06	0.00	0.25	0.86	0.23	0.92
11/10/2007	0.47	0.09	0.03	0.00	0.19	0.85	0.20	0.80
11/11/2007	0.49	0.08	0.03	0.00	0.19	0.86	0.18	0.74
11/12/2007	0.35	0.04	0.03	0.00	0.20	0.85	0.17	0.69
11/13/2007	0.31	0.06	0.03	0.14	0.24	0.84	0.15	0.59
11/14/2007	0.27	0.05	0.03	0.08	0.20	0.85	0.16	0.63
11/15/2007	0.34	0.06	0.03	0.40	0.33	0.89	0.10	0.42
11/16/2007	0.58	0.10	0.06	0.48	0.53	0.91	0.08	0.34

11/17/2007	0.66	0.11	0.06	0.00	0.32	0.87	0.19	0.75
11/18/2007	0.59	0.09	0.06	0.00	0.28	0.85	0.20	0.80
11/19/2007	0.48	0.09	0.03	0.03	0.25	0.85	0.19	0.75
11/20/2007	0.40	0.05	0.06	0.06	0.25	0.85	0.18	0.72
11/21/2007	0.36	0.07	0.03	0.06	0.23	0.85	0.18	0.70
11/22/2007	0.37	0.06	0.03	0.03	0.19	0.86	0.17	0.68
11/23/2007	0.36	0.07	0.03	0.03	0.20	0.85	0.16	0.66
11/24/2007	0.32	0.04	0.03	0.00	0.18	0.84	0.17	0.67
11/25/2007	0.30	0.07	0.03	0.00	0.17	0.85	0.16	0.62
11/26/2007	0.33	0.07	0.03	0.37	0.35	0.87	0.09	0.36
11/27/2007	0.42	0.07	0.06	1.59	0.89	1.00	0.00	0.00
11/28/2007	0.46	0.05	0.06	1.50	0.87	1.00	0.00	0.00
11/29/2007	0.43	0.05	0.06	1.47	0.88	0.96	0.00	0.00
11/30/2007	0.41	0.07	0.06	1.16	0.71	0.93	0.04	0.17
12/1/2007	0.36	0.07	0.03	0.17	0.26	0.84	0.19	0.76
12/2/2007	0.30	0.07	0.03	0.00	0.16	0.86	0.20	0.80
12/3/2007	0.34	0.06	0.03	0.14	0.22	0.85	0.16	0.63
12/4/2007	0.55	0.08	0.06	0.00	0.26	0.85	0.14	0.55
12/5/2007	0.38	0.07	0.06	0.03	0.22	0.85	0.14	0.55
12/6/2007	0.29	0.02	0.06	0.08	0.20	0.84	0.14	0.58
12/7/2007	0.26	0.05	0.03	0.06	0.16	0.86	0.15	0.60
12/8/2007	0.25	0.03	0.03	0.08	0.17	0.85	0.14	0.58
12/9/2007	0.27	0.04	0.03	0.06	0.16	0.86	0.14	0.54
12/10/2007	0.29	0.02	0.06	0.06	0.19	0.86	0.12	0.50
12/11/2007	0.31	0.06	0.03	0.03	0.19	0.86	0.13	0.51
12/12/2007	0.39	0.06	0.06	0.03	0.24	0.84	0.12	0.49
12/13/2007	0.54	0.08	0.06	0.06	0.31	0.88	0.10	0.39
12/14/2007	0.57	0.09	0.06	0.11	0.37	0.88	0.09	0.36
12/15/2007	0.75	0.10	0.08	0.00	0.31	0.88	0.13	0.51
12/16/2007	2.47	0.51	0.14	0.00	0.89	0.95	0.00	0.00
12/17/2007	1.21	0.23	0.08	0.03	0.67	0.92	0.02	0.08
12/18/2007	0.93	0.18	0.08	1.36	1.12	1.01	0.00	0.00
12/19/2007	0.82	0.15	0.08	1.50	1.07	1.03	0.00	0.00
12/20/2007	0.81	0.13	0.06	1.70	1.17	1.01	0.00	0.00
12/21/2007	0.74	0.11	0.08	1.53	1.05	1.01	0.00	0.00
12/22/2007	0.71	0.11	0.08	1.44	1.00	0.99	0.00	0.00
12/23/2007	0.75	0.10	0.08	1.30	0.97	0.98	0.00	0.00
12/24/2007	1.52	0.29	0.11	1.61	1.53	1.10	0.00	0.00
12/25/2007	1.40	0.27	0.11	1.27	1.31	1.07	0.00	0.00
12/26/2007	1.33	0.25	0.08	1.16	1.22	1.04	0.05	0.18
12/27/2007	1.63	0.32	0.11	1.61	1.56	1.10	0.00	0.00
12/28/2007	1.59	0.31	0.11	1.67	1.58	1.11	0.00	0.00
12/29/2007	1.66	0.32	0.11	1.76	1.66	1.15	0.00	0.00
12/30/2007	1.63	0.30	0.11	1.76	1.64	1.13	0.00	0.00
12/31/2007	1.60	0.30	0.11	2.18	1.79	1.15	0.00	0.00
1/1/2008	1.50	0.28	0.11	2.04	1.69	1.14	0.00	0.00
1/2/2008	1.36	0.26	0.08	1.95	1.54	1.12	0.04	0.15
1/3/2008	1.99	0.39	0.11	0.57	1.32	1.09	0.11	0.44
1/4/2008	1.64	0.32	0.11	0.74	1.22	1.04	0.12	0.49
1/5/2008	0.92	0.16	0.06	1.53	1.17	1.01	0.09	0.35
1/6/2008	0.83	0.13	0.08	1.56	1.10	1.03	0.08	0.32
1/7/2008	0.85	0.14	0.08	1.53	1.11	1.01	0.06	0.25

1/8/2008	1.02	0.17	0.08	1.50	1.19	1.05	0.04	0.17
1/9/2008	1.87	0.37	0.11	1.27	1.55	1.11	0.00	0.00
1/10/2008	2.26	0.45	0.14	1.44	1.84	1.16	0.00	0.00
1/11/2008	3.75	0.83	0.17	2.15	2.95	1.39	0.00	0.00
1/12/2008	4.40	0.98	0.14	2.83	3.57	1.50	0.00	0.00
1/13/2008	3.75	0.81	0.14	2.52	3.08	1.42	0.00	0.00
1/14/2008	2.84	0.58	0.14	4.33	3.38	1.46	0.00	0.00
1/15/2008	2.49	0.52	0.14	6.20	4.02	1.59	0.00	0.00
1/16/2008	2.28	0.50	0.11	5.97	3.79	1.56	0.00	0.00
1/17/2008	1.96	0.39	0.11	3.60	2.60	1.30	0.16	0.65
1/18/2008	2.20	0.47	0.11	3.79	2.83	1.36	0.11	0.44
1/19/2008	2.31	0.47	0.11	2.29	2.25	1.23	0.31	1.25
1/20/2008	2.08	0.44	0.11	2.12	2.04	1.22	0.34	1.36
1/21/2008	1.82	0.36	0.11	1.90	1.82	1.15	0.35	1.40
1/22/2008	1.47	0.29	0.11	1.98	1.66	1.14	0.33	1.34
1/23/2008	1.38	0.26	0.11	1.78	1.53	1.10	0.33	1.30
1/24/2008	1.28	0.22	0.11	0.62	0.96	0.99	0.47	1.87
1/25/2008	1.15	0.21	0.11	0.71	0.93	1.00	0.40	1.59
1/26/2008	1.04	0.20	0.08	1.39	1.15	1.06	0.25	1.02
1/27/2008	1.02	0.17	0.08	1.42	1.15	1.03	0.21	0.83
1/28/2008	1.00	0.16	0.08	1.19	1.04	1.03	0.18	0.72
1/29/2008	0.98	0.16	0.08	1.33	1.08	1.01	0.17	0.67
1/30/2008	1.13	0.20	0.08	1.02	1.05	1.01	0.17	0.68
1/31/2008	1.22	0.22	0.08	0.31	0.79	0.96	0.25	1.00
2/1/2008	1.80	0.33	0.11	0.79	1.29	1.06	0.10	0.40
2/2/2008	4.59	1.10	0.08	1.33	3.04	1.41	0.00	0.00
2/3/2008	4.13	0.99	0.08	0.79	2.58	1.30	0.03	0.11
2/4/2008	3.06	0.65	0.14	2.80	2.86	1.36	0.05	0.22
2/5/2008	3.30	0.72	0.14	5.61	4.20	1.60	0.00	0.00
2/6/2008	4.75	1.11	0.14	5.66	5.01	1.79	0.00	0.00
2/7/2008	8.86	2.23	0.06	6.17	7.41	2.28	0.00	0.00
2/8/2008	8.18	1.95	0.17	5.44	6.76	2.13	0.00	0.00
2/9/2008	5.72	1.36	0.14	7.13	6.15	2.00	0.00	0.00
2/10/2008	5.34	1.23	0.14	6.60	5.72	1.93	0.10	0.40
2/11/2008	4.37	1.01	0.14	6.94	5.33	1.84	0.10	0.40
2/12/2008	3.94	0.88	0.14	7.59	5.39	1.86	0.03	0.14
2/13/2008	6.41	1.52	0.14	7.64	6.73	2.13	0.00	0.00
2/14/2008	10.89	2.84	0.00	7.08	8.93	2.54	0.00	0.00
2/15/2008	10.55	2.73	0.03	5.72	8.16	2.26	0.00	0.00
2/16/2008	8.29	2.07	0.08	7.33	7.61	2.30	0.00	0.00
2/17/2008	6.30	1.51	0.14	8.13	6.91	2.15	0.11	0.43
2/18/2008	9.73	2.50	0.03	6.71	8.13	2.35	0.00	0.00
2/19/2008	12.10	3.16	0.00	5.78	9.01	2.55	0.00	0.00
2/20/2008	9.73	2.51	0.03	7.39	8.44	2.49	0.00	0.00
2/21/2008	7.17	1.75	0.11	8.01	7.31	2.23	0.29	1.14
2/22/2008	5.76	1.37	0.14	8.49	6.77	2.12	0.39	1.57
2/23/2008	4.88	1.12	0.14	7.30	5.75	1.93	0.61	2.46
2/24/2008	4.84	1.11	0.14	6.03	5.20	1.82	0.64	2.56
2/25/2008	4.47	1.02	0.14	4.95	4.57	1.69	0.70	2.80
2/26/2008	4.26	0.95	0.14	3.88	3.94	1.58	0.75	2.99
2/27/2008	5.21	1.22	0.14	4.28	4.64	1.73	0.46	1.85
2/28/2008	4.87	1.13	0.14	5.61	5.03	1.79	0.23	0.93

2/29/2008	4.10	0.94	0.14	4.45	4.15	1.60	0.47	1.87
3/1/2008	3.77	0.81	0.17	5.97	4.60	1.69	0.25	0.99
3/2/2008	3.61	0.78	0.14	5.66	4.38	1.68	0.23	0.91
3/3/2008	3.44	0.78	0.14	5.15	4.08	1.61	0.25	1.02
3/4/2008	3.99	0.91	0.14	4.59	4.09	1.62	0.21	0.85
3/5/2008	7.30	1.79	0.11	4.81	6.02	1.97	0.00	0.00
3/6/2008	7.91	1.94	0.11	5.61	6.66	2.12	0.00	0.00
3/7/2008	6.51	1.56	0.14	8.01	6.97	2.17	0.00	0.00
3/8/2008	9.78	2.50	0.06	5.38	7.63	2.28	0.00	0.00
3/9/2008	14.36	3.84	0.00	4.30	9.72	2.71	0.00	0.00
3/10/2008	11.24	2.91	0.00	6.46	8.90	2.48	0.00	0.00
3/11/2008	8.27	2.07	0.08	8.10	7.95	2.42	0.34	1.36
3/12/2008	6.85	1.67	0.11	9.63	7.82	2.23	0.37	1.47
3/13/2008	5.98	1.40	0.14	10.25	7.61	2.30	0.32	1.27
3/14/2008	5.33	1.24	0.14	9.94	7.14	2.20	0.35	1.38
3/15/2008	5.18	1.22	0.14	9.99	7.07	2.22	0.24	0.95
3/16/2008	4.90	1.13	0.14	9.57	6.77	2.12	0.24	0.97
3/17/2008	4.46	1.03	0.14	8.61	6.09	2.01	0.35	1.39
3/18/2008	4.04	0.91	0.14	6.71	5.06	1.82	0.59	2.37
3/19/2008	3.96	0.88	0.14	5.66	4.55	1.70	0.65	2.58
3/20/2008	5.10	1.18	0.14	6.06	5.35	1.87	0.35	1.38
3/21/2008	5.02	1.15	0.14	5.61	5.13	1.80	0.37	1.46
3/22/2008	4.41	1.00	0.17	5.63	4.80	1.77	0.42	1.70
3/23/2008	3.83	0.84	0.14	5.69	4.49	1.71	0.46	1.82
3/24/2008	3.31	0.71	0.14	6.00	4.37	1.66	0.40	1.61
3/25/2008	2.60	0.55	0.14	7.64	4.69	1.74	0.17	0.69
3/26/2008	2.52	0.51	0.14	7.93	4.74	1.74	0.07	0.26
3/27/2008	2.46	0.52	0.14	6.63	4.20	1.61	0.18	0.74
3/28/2008	2.67	0.56	0.11	6.40	4.18	1.62	0.14	0.54
3/29/2008	2.71	0.57	0.14	6.31	4.16	1.62	0.11	0.44
3/30/2008	2.50	0.50	0.14	6.17	4.00	1.58	0.14	0.58
3/31/2008	2.38	0.48	0.14	6.20	3.93	1.59	0.11	0.45
4/1/2008	2.19	0.45	0.11	7.25	4.27	1.65	0.00	0.00
4/2/2008	2.55	0.53	0.11	7.79	4.71	1.72	0.00	0.00
4/3/2008	2.35	0.48	0.14	5.63	3.71	1.53	0.15	0.61
4/4/2008	2.67	0.56	0.11	7.59	4.67	1.73	0.00	0.00
4/5/2008	3.13	0.69	0.14	7.96	5.12	1.82	0.00	0.00
4/6/2008	2.99	0.66	0.14	7.73	4.95	1.79	0.00	0.00
4/7/2008	2.59	0.53	0.14	7.19	4.46	1.68	0.00	0.00
4/8/2008	2.24	0.45	0.14	6.29	3.91	1.58	0.17	0.69
4/9/2008	2.05	0.39	0.14	7.05	4.10	1.61	0.05	0.20
4/10/2008	1.88	0.36	0.11	6.96	4.00	1.58	0.03	0.12
4/11/2008	1.73	0.34	0.11	6.80	3.85	1.56	0.01	0.06
4/12/2008	2.09	0.43	0.11	7.39	4.30	1.65	0.00	0.00
4/13/2008	2.70	0.56	0.14	7.33	4.61	1.70	0.00	0.00
4/14/2008	2.48	0.52	0.14	7.13	4.38	1.68	0.00	0.00
4/15/2008	2.11	0.41	0.11	7.11	4.20	1.61	0.00	0.00
4/16/2008	1.86	0.38	0.11	6.91	3.96	1.59	0.00	0.00
4/17/2008	1.69	0.35	0.11	6.74	3.79	1.56	0.00	0.00
4/18/2008	1.54	0.33	0.08	6.54	3.65	1.53	0.00	0.00
4/19/2008	1.38	0.26	0.11	6.43	3.52	1.50	0.00	0.00
4/20/2008	1.30	0.26	0.08	6.26	3.38	1.46	0.00	0.00

4/21/2008	1.20	0.22	0.08	6.26	3.33	1.43	0.00	0.00
4/22/2008	1.07	0.21	0.08	6.14	3.24	1.43	0.00	0.00
4/23/2008	1.03	0.16	0.08	6.12	3.17	1.41	0.00	0.00
4/24/2008	1.09	0.19	0.08	5.89	3.10	1.43	0.00	0.00
4/25/2008	1.06	0.19	0.08	5.52	2.90	1.40	0.00	0.00
4/26/2008	0.83	0.13	0.08	5.21	2.69	1.33	0.00	0.00
4/27/2008	0.73	0.12	0.08	5.15	2.61	1.33	0.00	0.00
4/28/2008	0.91	0.17	0.06	5.97	3.06	1.41	0.00	0.00
4/29/2008	3.01	0.65	0.14	6.96	4.61	1.70	0.00	0.00
4/30/2008	3.80	0.84	0.14	7.39	5.23	1.85	0.00	0.00
5/1/2008	2.89	0.63	0.14	7.93	4.95	1.78	0.00	0.00
5/2/2008	2.15	0.43	0.14	8.07	4.60	1.71	0.00	0.00
5/3/2008	1.92	0.41	0.11	7.81	4.38	1.68	0.00	0.00
5/4/2008	1.86	0.37	0.11	7.59	4.28	1.64	0.00	0.00
5/5/2008	1.84	0.37	0.11	6.43	3.76	1.54	0.12	0.46
5/6/2008	1.69	0.35	0.11	4.50	2.87	1.35	0.39	1.57
5/7/2008	1.53	0.28	0.11	1.50	1.48	1.09	0.82	3.30
5/8/2008	1.38	0.26	0.11	1.39	1.33	1.07	0.78	3.14
5/9/2008	1.24	0.23	0.08	1.87	1.46	1.11	0.61	2.46
5/10/2008	1.22	0.22	0.08	1.93	1.49	1.11	0.52	2.06
5/11/2008	1.13	0.20	0.08	1.78	1.39	1.07	0.48	1.91
5/12/2008	1.07	0.20	0.08	1.42	1.19	1.04	0.46	1.86
5/13/2008	0.99	0.17	0.08	0.76	0.85	0.96	0.52	2.07
5/14/2008	0.90	0.18	0.06	0.88	0.84	0.97	0.48	1.90
5/15/2008	0.84	0.15	0.08	1.27	1.01	1.00	0.36	1.43
5/16/2008	0.95	0.18	0.08	1.13	1.03	0.98	0.31	1.23
5/17/2008	1.32	0.26	0.08	1.27	1.26	1.06	0.22	0.87
5/18/2008	1.24	0.24	0.08	1.16	1.17	1.04	0.24	0.97
5/19/2008	1.01	0.17	0.08	1.25	1.08	1.01	0.27	1.08
5/20/2008	0.91	0.16	0.06	1.36	1.08	1.02	0.24	0.96
5/21/2008	0.93	0.17	0.08	1.22	1.05	1.02	0.21	0.85
5/22/2008	1.11	0.19	0.08	0.96	1.01	1.00	0.20	0.79
5/23/2008	1.16	0.20	0.11	0.71	0.93	1.00	0.21	0.84
5/24/2008	1.10	0.21	0.08	0.68	0.88	0.99	0.20	0.79
5/25/2008	1.08	0.20	0.08	0.59	0.81	0.97	0.19	0.77
5/26/2008	1.11	0.19	0.08	0.51	0.83	0.95	0.16	0.66
5/27/2008	0.86	0.15	0.08	0.99	0.92	0.98	0.12	0.48
5/28/2008	0.78	0.13	0.06	1.02	0.86	0.95	0.15	0.59
5/29/2008	0.67	0.12	0.06	0.76	0.67	0.94	0.22	0.88
5/30/2008	0.61	0.12	0.06	0.65	0.62	0.94	0.24	0.95
5/31/2008	0.56	0.09	0.06	0.68	0.60	0.93	0.23	0.94
6/1/2008	0.56	0.09	0.06	0.65	0.61	0.92	0.21	0.83
6/2/2008	0.49	0.08	0.03	0.76	0.56	0.92	0.19	0.76
6/3/2008	0.43	0.05	0.06	0.99	0.65	0.94	0.13	0.53
6/4/2008	0.45	0.06	0.06	1.25	0.77	0.96	0.08	0.32
6/5/2008	0.50	0.09	0.06	1.22	0.79	0.96	0.08	0.34
6/6/2008	0.56	0.10	0.06	1.13	0.80	0.96	0.12	0.48
6/7/2008	0.58	0.07	0.06	0.88	0.67	0.95	0.17	0.68
6/8/2008	0.52	0.07	0.06	0.76	0.64	0.92	0.19	0.77
6/9/2008	0.46	0.05	0.06	0.74	0.56	0.92	0.20	0.79
6/10/2008	0.42	0.06	0.06	0.65	0.52	0.90	0.19	0.77
6/11/2008	0.39	0.06	0.06	0.57	0.49	0.90	0.18	0.71

6/12/2008	0.35	0.05	0.03	0.48	0.40	0.87	0.18	0.71
6/13/2008	0.31	0.06	0.03	0.20	0.26	0.84	0.19	0.76
6/14/2008	0.28	0.03	0.06	0.17	0.22	0.86	0.19	0.75
6/15/2008	0.41	0.04	0.06	0.85	0.59	0.94	0.05	0.22
6/16/2008	0.45	0.06	0.06	0.51	0.46	0.90	0.10	0.41
6/17/2008	0.69	0.10	0.06	0.96	0.77	0.96	0.02	0.08
6/18/2008	0.52	0.07	0.06	0.45	0.47	0.91	0.14	0.55
6/19/2008	0.45	0.06	0.06	0.34	0.37	0.87	0.17	0.68
6/20/2008	0.38	0.07	0.06	0.31	0.33	0.89	0.17	0.67
6/21/2008	0.35	0.05	0.03	0.40	0.34	0.88	0.15	0.60
6/22/2008	0.31	0.06	0.03	0.28	0.30	0.89	0.15	0.59
6/23/2008	0.95	0.18	0.08	0.85	0.88	0.99	0.00	0.00
6/24/2008	1.59	0.31	0.11	1.30	1.42	1.08	0.00	0.00
6/25/2008	1.84	0.37	0.11	1.47	1.62	1.13	0.00	0.00
6/26/2008	1.30	0.26	0.08	1.76	1.48	1.10	0.00	0.00
6/27/2008	0.93	0.17	0.08	3.00	1.81	1.17	0.00	0.00
6/28/2008	0.79	0.15	0.06	4.05	2.17	1.23	0.00	0.00
6/29/2008	0.97	0.16	0.08	3.43	2.00	1.20	0.00	0.00
6/30/2008	0.75	0.15	0.06	3.00	1.71	1.12	0.00	0.00
7/1/2008	0.62	0.12	0.06	1.42	0.97	0.98	0.20	0.79
7/2/2008	0.66	0.10	0.06	0.96	0.76	0.97	0.27	1.09
7/3/2008	0.59	0.09	0.06	0.88	0.71	0.94	0.34	1.35
7/4/2008	0.54	0.08	0.06	1.05	0.74	0.96	0.37	1.47
7/5/2008	0.53	0.09	0.06	0.71	0.60	0.93	0.38	1.52
7/6/2008	0.49	0.08	0.03	0.62	0.53	0.91	0.38	1.53
7/7/2008	0.43	0.05	0.06	1.02	0.68	0.94	0.30	1.19
7/8/2008	0.37	0.06	0.03	2.49	1.27	1.06	0.05	0.19
7/9/2008	0.32	0.05	0.03	2.55	1.27	1.05	0.00	0.01
7/10/2008	0.32	0.05	0.03	2.43	1.22	1.05	0.05	0.22
7/11/2008	0.40	0.06	0.06	0.57	0.45	0.91	0.35	1.39
7/12/2008	0.30	0.07	0.03	0.37	0.33	0.89	0.37	1.48
7/13/2008	0.23	0.03	0.02	0.40	0.29	0.84	0.35	1.39
7/14/2008	0.20	0.02	0.03	0.34	0.26	0.84	0.31	1.23
7/15/2008	0.18	0.02	0.03	0.31	0.22	0.85	0.27	1.09
7/16/2008	0.17	0.02	0.03	0.27	0.21	0.84	0.24	0.97
7/17/2008	0.15	0.02	0.02	0.24	0.21	0.84	0.21	0.85
7/18/2008	0.13	0.02	0.02	0.23	0.18	0.84	0.19	0.76
7/19/2008	0.11	0.01	0.02	0.26	0.16	0.86	0.17	0.68
7/20/2008	0.11	0.01	0.02	0.23	0.13	0.86	0.17	0.68
7/21/2008	0.20	0.03	0.03	1.47	0.75	0.95	0.03	0.11
7/22/2008	0.15	0.02	0.02	0.49	0.31	0.88	0.25	1.02
7/23/2008	0.30	0.07	0.03	1.16	0.67	0.94	0.16	0.63
7/24/2008	2.34	0.49	0.14	4.13	3.04	1.41	0.00	0.00
7/25/2008	2.64	0.53	0.14	7.16	4.47	1.70	0.00	0.00
7/26/2008	2.07	0.42	0.11	6.91	4.08	1.64	0.00	0.00
7/27/2008	1.57	0.30	0.08	6.60	3.65	1.53	0.00	0.00
7/28/2008	1.56	0.31	0.08	5.69	3.28	1.44	0.13	0.52
7/29/2008	1.30	0.25	0.08	4.05	2.42	1.28	0.38	1.52
7/30/2008	1.03	0.16	0.08	2.32	1.52	1.11	0.65	2.60
7/31/2008	0.83	0.13	0.08	2.10	1.34	1.07	0.63	2.53
8/1/2008	0.72	0.11	0.08	2.35	1.39	1.08	0.51	2.03
8/2/2008	0.62	0.12	0.06	1.70	1.07	1.02	0.53	2.12

8/3/2008	0.66	0.11	0.06	1.73	1.07	1.03	0.49	1.97
8/4/2008	0.70	0.12	0.08	1.98	1.22	1.05	0.37	1.49
8/5/2008	0.56	0.09	0.06	2.35	1.31	1.07	0.30	1.19
8/6/2008	0.69	0.10	0.06	2.69	1.52	1.11	0.22	0.88
8/7/2008	1.06	0.19	0.08	2.21	1.52	1.11	0.21	0.84
8/8/2008	2.20	0.47	0.11	2.94	2.46	1.28	0.00	0.00
8/9/2008	3.66	0.79	0.17	1.98	2.82	1.37	0.00	0.00
8/10/2008	3.29	0.70	0.14	2.24	2.76	1.32	0.00	0.00
8/11/2008	2.54	0.55	0.11	3.31	2.82	1.35	0.09	0.36
8/12/2008	1.95	0.40	0.11	3.68	2.62	1.34	0.27	1.09
8/13/2008	1.71	0.33	0.11	3.34	2.35	1.27	0.42	1.68
8/14/2008	1.54	0.27	0.11	3.06	2.15	1.22	0.47	1.87
8/15/2008	1.44	0.29	0.08	2.27	1.73	1.16	0.55	2.20
8/16/2008	1.55	0.32	0.08	1.02	1.26	1.06	0.70	2.82
8/17/2008	1.47	0.29	0.11	0.65	1.06	1.03	0.75	3.01
8/18/2008	1.29	0.21	0.11	1.10	1.16	1.05	0.67	2.66
8/19/2008	1.08	0.19	0.08	2.38	1.60	1.14	0.43	1.72
8/20/2008	0.91	0.17	0.06	2.15	1.38	1.08	0.42	1.69
8/21/2008	0.77	0.13	0.06	1.67	1.15	1.01	0.44	1.74
8/22/2008	0.69	0.11	0.06	1.44	0.98	1.00	0.42	1.66
8/23/2008	0.61	0.12	0.06	0.74	0.65	0.94	0.46	1.85
8/24/2008	0.57	0.08	0.06	0.68	0.58	0.95	0.41	1.64
8/25/2008	0.54	0.08	0.06	0.74	0.59	0.94	0.34	1.36
8/26/2008	0.48	0.09	0.03	1.10	0.75	0.95	0.23	0.93
8/27/2008	0.44	0.04	0.06	0.65	0.51	0.91	0.25	1.02
8/28/2008	0.41	0.07	0.06	0.28	0.35	0.89	0.25	1.00
8/29/2008	0.37	0.05	0.03	0.23	0.32	0.87	0.22	0.89
8/30/2008	0.35	0.04	0.03	0.25	0.30	0.89	0.19	0.76
8/31/2008	0.33	0.04	0.03	0.23	0.29	0.85	0.18	0.72
9/1/2008	0.29	0.03	0.06	0.20	0.23	0.85	0.17	0.67
9/2/2008	0.26	0.02	0.06	0.17	0.20	0.84	0.16	0.65
9/3/2008	0.24	0.03	0.04	0.20	0.19	0.86	0.16	0.65
9/4/2008	0.22	0.03	0.03	0.15	0.19	0.86	0.16	0.63
9/5/2008	0.23	0.03	0.03	0.11	0.17	0.85	0.15	0.59
9/6/2008	0.53	0.09	0.06	0.68	0.57	0.91	0.04	0.15
9/7/2008	5.15	1.19	0.14	4.02	4.51	1.69	0.00	0.00
9/8/2008	5.11	1.20	0.14	4.13	4.56	1.70	0.00	0.00
9/9/2008	3.67	0.84	0.14	5.89	4.54	1.69	0.00	0.00
9/10/2008	2.43	0.52	0.11	5.95	3.88	1.56	0.21	0.84
9/11/2008	1.83	0.38	0.11	5.44	3.33	1.48	0.40	1.59
9/12/2008	1.50	0.29	0.11	4.28	2.66	1.34	0.56	2.24
9/13/2008	1.39	0.25	0.11	2.49	1.82	1.15	0.74	2.97
9/14/2008	1.55	0.32	0.08	2.52	1.88	1.20	0.62	2.48
9/15/2008	1.55	0.32	0.08	1.84	1.64	1.13	0.63	2.50
9/16/2008	1.54	0.27	0.11	0.88	1.21	1.06	0.67	2.68
9/17/2008	1.38	0.26	0.11	0.65	1.01	1.03	0.64	2.56
9/18/2008	1.19	0.22	0.08	0.17	0.70	0.94	0.65	2.60
9/19/2008	1.06	0.21	0.08	0.03	0.61	0.92	0.62	2.49
9/20/2008	0.94	0.17	0.08	0.06	0.53	0.91	0.54	2.16
9/21/2008	0.84	0.16	0.08	0.06	0.47	0.92	0.48	1.90
9/22/2008	0.76	0.14	0.06	0.06	0.42	0.89	0.43	1.72
9/23/2008	0.71	0.11	0.08	0.17	0.49	0.90	0.37	1.46

9/24/2008	0.64	0.12	0.06	0.99	0.76	0.97	0.22	0.87
9/25/2008	0.63	0.11	0.06	1.36	0.95	0.98	0.10	0.41
9/26/2008	1.29	0.21	0.11	3.65	2.25	1.26	0.00	0.00
9/27/2008	2.16	0.42	0.14	5.78	3.66	1.52	0.00	0.00
9/28/2008	3.33	0.75	0.14	6.46	4.55	1.71	0.00	0.00
9/29/2008	3.17	0.68	0.14	6.60	4.53	1.70	0.00	0.00
9/30/2008	2.50	0.50	0.14	5.86	3.87	1.57	0.00	0.00

APPENDIX B:
Development of Mercury Bioaccumulation Factors (BAFs)
from Available Surface Water and Fish Tissue Data.

Species-specific bioaccumulation factors (BAFs) for mercury were developed for largemouth bass and yellow perch based on available pairings of mercury concentrations in surface water and fish tissue in the Sudbury River. Mercury bioaccumulation factors were developed using pairings of methylmercury concentrations in filtered surface water collected from Reach 3 (Reservoir 2) and total mercury in largemouth bass and yellow perch fillets collected during approximately the same time interval. BAFs were calculated using total mercury fillet data. Because site-specific data indicate that 89-99% of mercury detected in the axial muscle of fish (i.e., fillet) is methylated, it was assumed that all of the mercury detected in fish tissue is methylated.

Methylmercury in surface water was monitored in Reservoir 2 during seven (7) sampling events conducted between May 2007 and June 2008 (Table 1). Largemouth bass and yellow perch were collected from the same location in June 2008 (Table 2). Methylmercury concentrations from twenty-five (25) filtered surface water samples were paired with mercury concentrations from each of thirteen (13) largemouth bass fillet samples. The pairings resulted in a “distribution” data set of 325 separate BAFs for the largemouth bass. Likewise, the results of the surface water samples were paired with mercury concentrations from each of eight (8) yellow perch fillets resulting in a data set of 200 BAFs for the yellow perch.

To assess a measure of central tendency for the BAFs, it was first necessary to examine the shape of the distribution of each of the data sets to assess the use of normal parametric statistics to describe the mean or some other measure of central tendency. The individual data sets were plotted using frequency histograms to obtain a visual reference of the distribution (Figures 1 and 2). Based on these results, the distributions of both the largemouth bass and the yellow perch pairings were asymmetric and positively skewed and the assumption of normality did not have a reasonable analytic solution.

As such the bass and perch data sets were run through a series of distribution tests to determine the “best-fit” using Pro UCL software. Based on the results, a non-parametric approach (i.e. the Chebychev approach) provided the best fit for both the largemouth and the yellow perch data sets. Using the Chebychev methodology, mean BAFs of 14.3 e+06 and 4.3 E+06 were calculated for the largemouth bass and yellow perch, respectively. Figure 3 provides side-by-side box plot distributions of the largemouth bass and yellow perch BAFs with inclusion of the Chebychev means for comparison.

The final BAF for mercury uptake from surface water and bioaccumulation in fish fillet tissue in Reach 3 of the Sudbury River utilized the geometric mean which resulted in a BAF of 7.8 E+06.

TABLE 1 Filtered Methyl Mercury in Surface Water Reservoir #2 (Reach 3) May 2007 thru June 2008		
Year	Date	Filtered MeHg Concentration in Surface Water ng/L
2007	5/14/2007	0.252
		0.137
		0.105
	6/6/2007	0.402
		0.331
		0.361
		0.319
	7/17/2007	0.16
		0.1
		0.202
	9/6/2007	0.056
		0.026B
		0.024B
	10/9/2007	0.039B
		0.059
		0.038B
		0.032B
	3/26/2008	0.052
		0.042
		0.040B
		0.042B
	6/18/2008	0.25
		0.095
		0.091H
		0.068

Table 2
Summary of Total Mercury Concentrations
Detected in Fillet Samples of Yellow Perch and Largemouth Bass
Collected from Reservoir #2 (Reach 3) in June 2008

Analyte	Sample ID	Date Collected	Lab Sample ID	Result	Units
Yellow Perch					
Hg	S3-1-YP0001	06/05/2008	0831026-01	370	ng/g
Hg	S3-1-YP0002	06/05/2008	0831026-02	143	ng/g
Hg	S3-1-YP0003	06/05/2008	0831026-03	270	ng/g
Hg	S3-1-YP0004	06/05/2008	0831026-04	269	ng/g
Hg	S3-1-YP0005	06/05/2008	0831026-05	203	ng/g
Hg	S3-1-YP0006	06/05/2008	0831026-06	229	ng/g
Hg	S3-2-YP0007	06/05/2008	0831026-07	155	ng/g
Hg	S3-2-YP0008	06/05/2008	0831026-08	126	ng/g
Largemouth Bass					
Hg	S3-1-LB0001	06/05/2008	0832011-01	714	ng/g
Hg	S3-1-LB0002	06/05/2008	0832011-02	659	ng/g
Hg	S3-1-LB0003	06/05/2008	0832011-03	927	ng/g
Hg	S3-1-LB0004	06/05/2008	0832011-04	615	ng/g
Hg	S3-1-LB0005	06/05/2008	0832011-05	783	ng/g
Hg	S3-2-LB0006	06/05/2008	0831026-65	1010	ng/g
Hg	S3-2-LB0007	06/05/2008	0831026-66	794	ng/g
Hg	S3-2-LB0008	06/05/2008	0831026-67	690	ng/g
Hg	S3-2-LB0009	06/05/2008	0831026-68	908	ng/g
Hg	S3-2-LB0010	06/05/2008	0831026-69	547	ng/g
Hg	S3-3-LB0011	06/05/2008	0831026-70	834	ng/g
Hg	S3-3-LB0012	06/05/2008	0831026-71	1040	ng/g
Hg	S3-3-LB0013	06/05/2008	0831026-72	681	ng/g

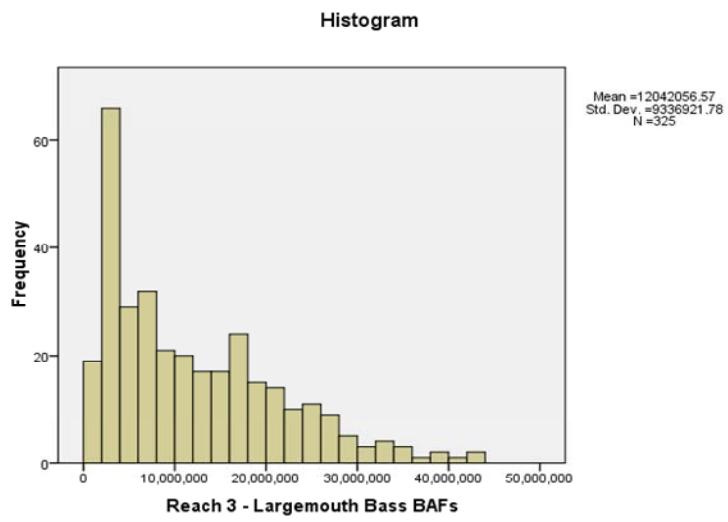


Figure 1
Frequency Distribution of Bioaccumulation Factors
(BAFs) for Largemouth Bass in
Reservoir #2 (Reach 3)

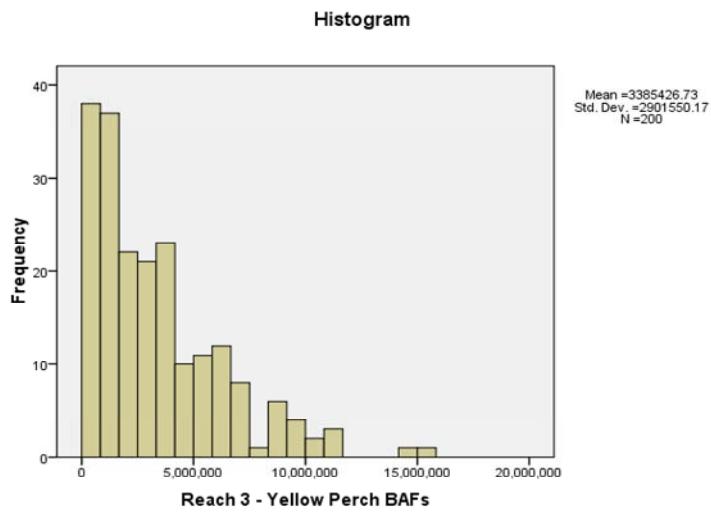


Figure 2
Frequency Distribution of Bioaccumulation Factors
(BAFs) for Yellow Perch in
Reservoir #2 (Reach 3)

